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BERGEY'S MANUAL OF

DETERMINATIVE BACTERIOLOGY

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BERGEY'S MANUAL OF DETERMINATIVE BACTERIOLOGY

A Key for the Identification of Organisms of the Class Schizomycetes

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PREFACE TO FIRST EDITION

The elaborate system of classification of the bacteria into families, tribes and genera by a committee on characterization and classification of the Society of American Bacteriologists (1917, 1920) has made it very desirable to be able to place in the hands of students a more detailed key for the identification of species than any that is available at present. The valuable book on "Determinative Bacteriology" by Professor F. D. Chester, published in 1901, is now of very little assistance to the student, and all previous classifications are of still less value, especially as earlier systems of classification were based entirely on morphologic characters.

It is hoped that this manual will serve to stimulate efforts to perfect the classification of bacteria, especially by emphasizing the valuable features as well as the weaker points in the new system which the Committee of the Society of American Bacteriologists has promulgated. The Committee does not regard the classification of species offered here as in any sense final, but merely a progress report leading to more satisfactory classification in the future.

The Committee desires to express its appreciation and thanks to those members of the Society who gave valuable aid in the compilation of material and the classification of certain species. Especial mention should be made of the following:

S. A. Waksman, New Jersey Agricultural College, New Brunswick, N. J., for assistance on genus *Actinomyces* and genus *Thiobacillus*.

I. C. Hall, University of California, Berkeley, Calif., for assistance on genus *Clostridium*.

W. G. Sackett, Agricultural Experiment Station, Fort Collins, Colo., for assistance on genus *Phytomonas*.

T. M. Rivers, Rockefeller Institute for Medical Research, New York, for assistance on genus *Hemophilus*.

L. A. Julianelle, Laboratories, Philadelphia General Hospital, Philadelphia, Pa., for assistance on genus *Encapsulatus*.

Max Levine, Iowa Agricultural College, Ames, Iowa, for assistance on a number of the species in tribe *Bacterieae.*

The assistance of all bacteriologists is earnestly solicited in the correction of possible errors in the text; in the collection of descriptions of all bacteria that may have been omitted from the text; in supplying more detailed descriptions of such organisms as are described incompletely; and in furnishing complete descriptions of new organisms that may be discovered, or in directing the attention of the Committee to publications of such newly described bacteria.

COMMITTEE ON MANUAL.

PREFACE TO SECOND EDITION

Through the coöperation of many bacteriologists the Committee has been enabled to correct errors and to amend descriptions of individual species, and wishes to express its appreciation for all the sympathetic criticisms of the Manual that have been received.

Sufficient time has not elapsed to make it possible to introduce many new species, though some species that were not included in the first edition have been added, and new species discovered and described since the preparation of the Manual, have also been included as far as these have come to the notice of the Committee.

The greatest changes in the present edition arise from the fact that several of the generic names that were adopted have since been found to be invalid and have been displaced by the earlier, valid names and in one instance by a slight change in the older, invalid name. The new generic names introduced are as follows:

Klebsiella for *Encapsulatus*
Kurthia for *Zopfius*
Rhodorhagus for *Rhodosphaera*
Borrelia for *Spironema*

It happens that several of these generic names are eponyms. The Committee has been criticised for the use of eponyms, but where such names have been introduced by others and have been found to be valid the Committee has had no choice but to recognize them. The Committee has not proposed eponyms for the new genera which it has created.

Genus *Nitrosococcus* has been added to Tribe *Nitrobacterieae*. An additional genus has been recognized in the family *Coccaceae* in order to separate the species which did not appear to belong in the genus in which they had been placed. The additional genus recognized is *Gaffkya* to include the distinctive tetrad forms.

The tribes of Family *Coccaceae* have been transposed so as to bring Genus *Staphylococcus* into Tribe *Micrococceae*. They appear to be more definitely related to the bacteria in this tribe than to the bacteria of Tribe *Streptococceae* in which they had been placed by the Committee on Classification and Nomenclature in their reports of 1917 and 1920.

The keys to the species of several of the genera have been rearranged so as to make the tracing of unknown species less difficult. This is a feature of the Manual to which the Committee has given a great deal of thought and attention.

The comparative study of several groups of bacteria made available considerable material which enabled the Committee to amplify the descriptions of some of the species and hence make their identification more definite. The attention of bacteriologists is directed to the great need for further studies along these lines so that the descriptions of other species may be amplified and corrected. As the results of such investigations are published they should be incorporated in future editions of the Manual.

In order that the Manual may become more valuable and of greater benefit to bacteriologists the Committee solicits the continued interest and coöperation of all those who are able to assist it in its work.

COMMITTEE ON MANUAL.

PREFACE TO THIRD EDITION

The Committee on the Manual has had most cordial coöperation of numerous bacteriologists in the collection of newly described organisms from the literature and in the amplification of descriptions of organisms described in previous editions. More than two hundred additional organisms are included in the revision.

Two additional tribes have been recognized, *Protaminobacterieae* and *Propionibacterieae*, each containing a single genus. Both genera represent important species of soil (and possibly water) bacteria which had been recognized before but not described in detail.

Genus *Eberthella* has been divided by separating the dysentery group from the typhoid group, the former group being placed in Genus *Shigella* Castellani and Chalmers while the latter group is retained as genus *Eberthella*.

Four additional genera have also been recognized in Family *Mycobacteriaceae*, each Genus representing characteristic groups of soil bacteria, namely *Mycoplana* Gray and Thornton, *Cytophaga* Winogradsky, *Cellvibrio* Winogradsky, and *Cellfalcicula* Winogradsky.

The greater number of newly described bacteria which have been included in the revision fall in Genera *Flavobacterium*, *Pseudomonas*, *Phytomonas*, *Lactobacillus* and *Bacillus*. These additions have necessitated the reconstruction of the keys for these genera.

Another change in the Manual is an attempt to arrange the genera of Tribe *Bacterieae* in a way which appears to be more logical. This required the construction of a new key for Tribe *Bacterieae* as well as the transposing of the locations of the genera in the tribe.

The Committee feels that intensive studies are needed on the bacteria in different genera in order that future classifications can be based on more detailed knowledge of all the characters of the bacteria in each genus. After such extended studies have been made it will be possible to classify the bacteria on more

definite biologic foundations. It is probable that studies of this nature will suggest the separation of some of the recognized genera into one or more new genera.

The Committee wishes to thank all those bacteriologists who have aided it in making the revision and invites bacteriologists to take under consideration the collection of data which can be utilized in making future revisions.

COMMITTEE ON MANUAL.

PREFACE TO FOURTH EDITION

The interest in the Manual by bacteriologists has increased greatly, during the past two years, not only on the part of those in the United States but also those in other parts of the world, as indicated by the number of reprints of descriptions of new organisms sent to the Committee by the authors, and also by numerous helpful suggestions for the improvement of the MANUAL.

Two new genera have been recognized in Tribe *Bacterieae*, namely Genus *Brucella* and Genus *Listerella*. Genus *Pfeifferella* has been combined with Genus *Actinobacillus*.

Information was available for the amplification of the descriptions of species of the following genera: *Leuconostoc*, *Propionibacterium*, *Bacterioides*, and Order *Myxobacteriales*.

Descriptions of about 50 new species have been included while several organisms have been omitted as distinct species and the names recognized as synonyms for other species.

The intensive studies conducted in different laboratories on the species of several genera have yielded results that were helpful to the Committee in making this revision of the MANUAL.

Much further intensive study is urgently needed to supply information on other genera, especially those in which large numbers of species are included. It is probable that certain of the organisms at present recognized as distinct species are, in reality, synonyms for other species.

The Committee has had the assistance of Dr. C. D. Kelly, of Geneva, N. Y., in developing the synonymy and bibliographic references used in the MANUAL.

The Committee appreciates the assistance of Prof. G. P. Van Eseltine of Geneva, New York, in bringing the spelling and endings of scientific names into harmony with the latest international rules covering this matter (Jour. Bact., *26*, 1933, 569).

The Committee is under obligations to Prof. R. E. Buchanan for a new introduction prepared for this edition and for a revision of the Order *Myxobacteriales*.

The Committee appreciates greatly the interest and cooperation of bacteriologists in supplying reprints of papers containing results of their work which are helpful in classifying the bacteria.

COMMITTEE ON MANUAL.

CONTENTS

INTRODUCTION

Suggestions for the Use of the Manual in Classifying Unknown Organisms

No organism can be classified before we have determined, through detailed study, its morphologic, cultural and pathogenic characters.

After complete study of all the characters of the organism has been made, turn to page 28 and ascertain *first* in which order the organism belongs.

When the order has been ascertained, refer to the table of contents, pages xiii to xvi and note the page of the Manual on which a key to that order is given. In this key ascertain the family or subfamily to which the organism belongs.

When the family or subfamily has been decided on, again refer to the table of contents, pages xiii to xvi, and find the page of the Manual on which a key to that family or subfamily is given. In this key ascertain the tribe to which the organism belongs.

When the tribe has been decided on, again refer to the table of contents, pages xiii to xvi and find the page of the Manual on which a key to the tribe is given. In this key ascertain the genus to which the organism belongs.

When the genus has been decided on, again refer to the table of contents, pages xiii to xvi and find the page of the Manual on which a key to that genus is given. In this key, trace out the species under investigation.

For example, if one wishes to trace a short, motile, Gram-negative rod that grows well on ordinary culture media at 37.5°C., fermenting dextrose and lactose with production of gas, and not liquefying gelatin, producing no pigment on any culture media, and with negative reaction for acetyl-methyl-carbinol, producing indol and reducing nitrates, consult the key to the orders on page 28. In this key *1. Simple and undifferentiated forms, the true bacteria, Order 1. Eubacteriales,* indicates that our unknown organism belongs to this order.

We now refer to the table of contents, pages xiii to xvi, and find that the key to Order 1 is on page 28.

We next attempt to ascertain the family to which the organism belongs by tracing it through the key to the families of the order *Eubacteriales* p. 28.

1. Organisms usually rod-shaped, occasionally spherical, or nearly so. Endospores not ordinarily formed. May use in their metabolism carbon, hydrogen, sulphur, or nitrogen, or simple compounds of these. May oxidize ethyl alcohol to acetic acid. Family I. Nitrobacteriaceae.

Since the organism does not secure growth energy in the manner indicated for Family I, we now proceed to

2. Not securing growth energy as under 1.

a. Cells spherical. Family II, Coccaceae. This does not correspond with the morphology of the organism being studied. We proceed to

aa. Cells not spherical.

b. Cells spiral. Family III, Spirillaceae. This does not correspond with the morphology of the organism. We proceed to

bb. Cells straight rods.

c. Endospores not formed. Cells motile or non-motile. Family IV, Bacteriaceae. This appears to fit our unknown organism.

We now refer to the table of contents, pages xiii to xv, and ascertain the page of the MANUAL on which the key to family *Bacteriaceae* is supplied. This key will be found on page 122.

In the key to the tribes of family *Bacteriaceae* we ascertain the tribe to which our organism belongs.

1. Saprophytes or parasitic for plants. Optimum temperature 30°C. or less. Since our unknown organism grows well at 37.5°C. we proceed to

2. Parasitic for animals. Optimum temperature 37.5°C.

a. Aerobic.

b. Show bipolar staining. Since the organism stains uniformly we proceed to

bb. Do not show bipolar staining.

c. Encapsulated. As the organism shows no capsule we proceed to

cc. Not encapsulated.

d. Require blood medium. Since the organism grows well on ordinary culture media we proceed to

dd. Do not require blood medium.

Tribe XII. Bacterieae. This appears to correspond to the characters exhibited by our organism.

We refer to the table of contents, pages xiii to xv, and find that tribe *Bacterieae* is described on page 342. Here we find a key to the genera of tribe *Bacterieae.*

A. Ferment dextrose with the production of acid or acid and gas.

1. Gas formed from dextrose.

a. Gas formed from lactose.

b. Acetyl-methyl-carbinol not formed from dextrose.

Genus XVII. Escherichia.

This description appears to correspond with that of our unknown organism. We find the key to the species of Genus *Escherichia* follows the key to the Tribe *Bacterieae.* On tracing our organism in this key we find that it corresponds to *Escherichia coli.* Brief description of this organism is found on page 344.

If for any reason the student is unable to trace his unknown organism, several explanations may be suggested: (1) Failure to follow the proper leads in the key in tracing the organism. (2) Incomplete data regarding the characters of the organism he is trying to classify. (3) Incomplete description in the MANUAL of the organism under investigation. (4) The organism was not included in the MANUAL because no detailed study of it was found in the literature.

ABRIDGED KEY OF THE BACTERIAL FAMILIES, TRIBES AND GENERA OF ORDER EUBACTERIALES.

With the Principal Characters of Different Genera, to Aid the Student in Placing a Particular Species*

PLANT KINGDOM

Phylum: *Thallophyta*

Class: *Schizomycetes*

Orders:

Eubacteriales *Actinomycetales* *Chlamydobacteriales*
Thiobacteriales *Myxobacteriales* *Spirochaetales*

Eubacteriales:

Simple, undifferentiated forms—no true branching
Spheres, short or long straight rods, curved rods
Motile or non-motile
Some species pigmented
Some species store volutin, glycogen or fat
Sulfur and iron not stored as visible particles

Actinomycetales:

Mold like
Rod-shaped or filamentous—decided tendency to true branching
Many pathogenic forms show distinct enlargement of ends when growing in the animal body or even in culture media
Non-motile
Conidia may be formed

Chlamydobacteriales:

Sheathed filaments
Alga-like, typically water forms
False branching in many species
Sheath frequently impregnated with iron
Conidia may be developed
Sulfur granules or bacteriopurpurin absent

Thiobacteriales:

Not sheathed
Sulfur bacteria
Spheres, short or long straight rods, short spirals or filaments
Conidia not formed
Cells contain sulfur granules, bacteriopurpurin and bacteriochlorin

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* Adapted from Obold and Diehm, Manual of Microbiology, F. A. Davis & Co., Philadelphia, Pa., 1932, 120.

Myxobacteriales:
Mold-like, slimy
Motile, rod-like forms
gelatinous base, pseudopodium-like aggregation
cyst-producing resting stage
Conidia absent
Sulfur granules and bacteriopurpurin absent
Most species chromogenic

Spirochaetales:
Protozoan like
Slender, flexible spirals
Endospores absent
Multiplication by transverse and possibly by longitudinal division

Eubacteriales

FAMILIES:
Nitrobacteriaceae *Coccaceae* *Spirillaceae* *Bacteriaceae* *Bacillaceae*

Nitrobacteriaceae:
Prototrophic (utilize simple inorganic compounds—C, H, S, N or simple compounds of these; may oxidize ethyl alcohol to acetic acid)
Usually rod-shaped
Motile or non-motile
Branched involution forms
Endospores absent
Non parasitic (except *Rhizobium*)
Usually water or soil forms

Coccaceae:
Spheres—pairs, tetrads, packets, chains or irregular masses
Few species motile
Endospores absent
Usually grow on ordinary culture media

Spirillaceae:
Short curved rods or in spiral chains
Not flexuous
Many species motile (polar flagella)
Grow well on ordinary culture media

Bacteriaceae:
Straight rods
Endospores absent
Motile or non-motile
Many forms chromogenic
Bacteriopurpurin and bacteriochlorin absent
Sulfur granules absent
Require complex organic substances for food (metatrophic)

Not prototrophic
May act on carbohydrates with the production of acid or acid and gas
Some species hydrolyze starch

Bacillaceae:
Endospores formed
Rods
Motile or non-motile
Usually use complex protein substances for food
Many species use simple sugars and starch

FAMILY: **Nitrobacteriaceae**

TRIBES: *Nitrobacterieae* (prototrophic) *Azotobacterieae* (fix free nitrogen)

GENUS:

Nitrobacterieae:
- *Hydrogenomonas*—oxidize hydrogen to form water
- *Methanomonas*—oxidize methane to form CO_2 and water
- *Carboxydomonas*—oxidize CO to form CO_2
- *Nitrosomonas*—oxidize ammonia to form nitrites (rods)
- *Nitrosococcus*—oxidize ammonia to form nitrites (cocci)
- *Nitrobacter*—oxidize nitrites to nitrates
- *Acetobacter*—oxidize alcohol to form acetic acid
- *Thiobacillus*—oxidize elementary sulfur and compounds of sulfur

Azotobacterieae:
- *Azotobacter*—fix atmospheric nitrogen when growing in solutions of carbohydrates
- *Rhizobium*—fix free nitrogen when growing symbiotically on the roots of *Leguminosae*

FAMILY: **Coccaceae**

TRIBES: *Streptococceae* *Neisserieae* *Micrococceae*

Streptococceae: Cell division in one plane only, occurring in pairs and in short or long chains
Parasitic (except *Leuconostoc* and certain streptococci from dairy products)—certain species require blood serum for cultivation
Gram positive

Neisserieae: Occur as singles, pairs or tetrads
Require special media with blood or blood serum for cultivation

Micrococceae: Singles, pairs and frequently irregular masses. Generally Gram positive

GENUS:

Streptococceae:

Diplococcus—pairs, Gram positive, parasites, difficult to cultivate
Streptococcus—short or long chains, sometimes pairs, Gram positive, many parasites
Leuconostoc—pairs or chains, grow in cane sugar solutions and fruit juices, saprophytes

Neisserieae:

Neisseria—Gram negative, usually pairs

Micrococceae:

Staphylococcus—Occur singly, in pairs and irregular masses
Mesophilic and usually parasitic
Gelatin liquefied
Usually Gram positive
Some simple carbohydrates fermented with formation of acid

Gaffkya—usually tetrads in special media, pairs and irregular masses in ordinary media
Gram positive

Micrococcus—Occur in plates or irregular masses
Acid formed in dextrose and lactose by some species
Gelatin may or may not be liquefied

Sarcina—Saprophytes or facultative parasites
Division in three planes—eight members in a group
Acid may be formed in dextrose
Lactose usually not attacked
Gelatin frequently liquefied

Rhodococcus—Saprophytes
Occur in groups or irregular packets
Slight acidity in dextrose; none in lactose
Gelatin rarely liquefied
Red pigment formed

FAMILY: **Spirillaceae**

GENUS:

Vibrio: Short, bent rods, rigid, single or united into spirals
Motile with single polar flagellum (rarely two or three)
Many species liquefy gelatin and are active ammonifiers
Aerobic and facultative anaerobic
Endospores absent
Usually Gram negative
Water forms; a few parasites

Spirillum: Rods of varying thickness, length and pitch of spiral, forming either long screws or portions of a turn

Usually motile—lopotrichous (5 to 20 flagella) half circular, rarely curled. Sometimes amphitrichous (number varying)
Found in water and putrid infusions

FAMILY: FAMILY: BACTERIACEAE

TRIBE:

Bacteriaceae:

Chromobacterieae—Mostly saprophytes, Gram negative, chromogenic, mesophilic

Protaminobacterieae—Water and soil bacteria, Gram negative, chromogenic, mesophilic

Cellulomonadeae—Non-chromogenic or only pale yellow pigment produced, cellulose digested, Gram negative

Achromobacterieae—Non-chromogenic motile or non-motile, Gram negative

Erwineae—Plant pathogens

Lactobacilleae—Rods, often long and slender, Gram positive, non-motile. Generally produce acid (mostly lactic). Gas, if formed is CO_2. Organisms somewhat thermophilic and microaerophilic

Propionibacterieae—Non-motile, Gram positive rods—under anaerobic conditions as short and under aerobic conditions as long irregular rod-shaped cells. Ferment lactic acid, carbohydrates, and polyalcohols with formation of propionic and acetic acids with CO_2. Complex organic nitrogen compounds required for development. Catalase formed.

Kurthieae—Gram positive rods; grow freely on artificial media.

Pasteurelleae—Gram negative rods, showing bipolar staining. Non-motile. Parasitic. Slight fermentative powers

Klebsielleae—Short, encapsulated rods with somewhat rounded ends. Usually occur singly. Gram negative. Ferment a number of carbohydrates with formation of acid and gas. Encountered chiefly in respiratory tract of man. Aerobic; grow well on artificial media

Hemophileae—Parasitic. Non-motile. Gram negative. Minute rod-shaped cells. Grow only in presence of hemoglobin, ascitic or other body fluids

Bacteriaceae—*cont.*:	*Bacterieae*—Gram negative; grow well on artificial media. Many species attack carbohydrates with the formation of acid or acid and gas. Occur commonly in the intestinal tract of animals. Relatively few species liquefy gelatin. When motile—flagella are usually peritrichous *Bacteroideae*—Motile or non-motile rods Grow well on ordinary culture media Obligate anaerobes

TRIBE:	GENUS:
Chromobacterieae:	*Serratia*—small, aerobic rods, producing red or pink pigment on agar or gelatin *Flavobacterium*—small, aerobic rods, producing yellow pigment in agar or gelatin *Chromobacterium*—Small, aerobic rods, producing a violet pigment on solid media *Pseudomonas*—small, aerobic rods, producing green or blue-green pigment (soluble)
Protaminobacterieae:	*Protaminobacter*—small, Gram negative rods, attack one or more of the lower alkylamines
Cellulomonadeae:	*Cellulomonas*—small rods, rounded ends, non-spore forming, occurring in soil, digest cellulose. Motile or non-motile
Achromobacterieae:	*Achromobacter*—rods, non-chromogenic, motile or non-motile, occurring in water and soil. Gram negative
Erwinieae:	*Erwinia*—motile rods, peritrichous flagella, plant pathogens *Phytomonas*—rods, motile or non-motile, polar flagella, plant pathogens
Lactobacilleae:	*Lactobacillus*—description given for tribe
Propionibacterieae:	*Propionibacterium*—description given for tribe
Kurthieae:	*Kurthia*—long rods, occurring in evenly curved chains, motile. Proteus-like growth on media. Carbohydrates and gelatin not attacked. Hydrogen sulphide not formed. Facultative anaerobic *Listerella*—short rods, singly or in couples, motile. Growth on media almost transparent. Strictly aerobic. Certain carbohydrates attacked

Pasteuralleae:	*Pasteurella*—aerobic, facultative, parasitic
Klebsielleae:	*Klebsiella*—description given for tribe
Hemophileae:	*Hemophilus*—aerobic *Dialister*—anaerobic
Bacterieae:	*Escherichia*—acid and gas from dextrose, acetyl-methyl-carbinol not formed *Aerobacter*—acid and gas from dextrose, acetyl-methyl-carbinol formed *Proteus*—acid and gas lactose—negative (acid may be formed) from dextrose, acid and gas from sucrose *Salmonella*—dextrose acid and gas lactose—negative sucrose—negative Some forms pathogenic *Eberthella*—acid but no gas from dextrose, motile, many forms pathogenic *Shigella*—acid but no gas from dextrose, non-motile, many forms pathogenic *Brucella*—short oval rods, non-motile, alkaline reaction in milk, pathogenic *Alcaligenes*—no action on carbohydrates, non-pathogenic
Bacteroideae:	*Bacteroides*—description given for tribe

FAMILY: **Bacillaceae**

GENUS:

Bacillus:	Aerobic, spore-forming rods, mostly saprophytic
Clostridium:	Anaerobic, spore-forming rods, often parasitic

HOW BACTERIA ARE NAMED AND IDENTIFIED*

Some principles of taxonomy and nomenclature. "Taxonomy is that branch of biology that deals with the orderly arrangement of plants and animals." (Johnson, Taxonomy of the Flowering Plants, New York, 1931, p. 3.)

The necessity for applying names to species or kinds of bacteria is self-evident. It is highly desirable that the name applied to an organism by one person should be understood by others. It is further desirable that as far as practicable all individuals use the same name for the same kind of organism. It is helpful, therefore, if there can be an agreement regarding the method of naming organisms, and as to the correct name for each organism. The term *nomenclature* is applied to the naming of plants and animals, and under this term may be included all discussions as to methods of naming and correctness of particular names.

It is not enough that bacteria be named. Some method of classification of the bacteria is essential if the names are to be rendered accessible and available, and identification of unknown forms be made possible. *Taxonomy* is that branch of biology which treats of classification. It is apparent that taxonomy must be dependent in part for its satisfactory development upon nomenclature. Even though there may not be agreement among bacteriologists as to the exact classification that is to be used, nevertheless it is highly desirable that there be agreement as to some of the fundamental characteristics of satisfactory biological classifications in general.

What kinds of names are used. Two kinds of names are commonly given to the different kinds of plants and animals, the common, provincial, vernacular or casual names on the one hand and the international or scientific names on the other. These should be carefully differentiated, and their respective advantages and disadvantages noted.

* **Contributed by Prof. R. E. Buchanan, Iowa State College, Ames, Iowa.**

It is inevitable, and on the whole probably desirable, that for each kind of familiar animal or plant in each language there will be coined a name. Usually the name for the same organism will be different in each language. For example, we have in English *Oak*, in German *Eiche*, in Latin, *Quercus*, etc. For many uncommon kinds, however, there may be no such vernacular names developed. There have been, of course, many casual or vernacular names given to kinds of bacteria. In English we speak of the tubercle bacillus, the typhoid germ, the gonococcus, the Welch bacillus, the golden pus coccus, and many others. Similarly, we find in German Typhusbazillen and in French bacille typhique, enterococcus, etc. The use of these common names offers certain advantages. It does away frequently, with the necessity of repeating longer and more formal scientific names. Not infrequently scientific names may be adopted into a language, and converted into vernacular names. For example, the English name *aster* and the scientific generic name *Aster* are applied to the same group. This is frequently a convenience, but there are also some difficulties, which will be emphasized below.

In contrast to common, vernacular or casual names, the scientific name for each kind of organism (each plant or animal) is supposed to be the same in all countries and in all languages. When such a scientific name is used no question should arise in any language as to what organism is intended. The names thus applied are supposed to conform to certain general rules that have been formulated by international agreement. Obviously the use of such names is advantageous whenever one is desirous of accuracy, and of being definitely understood in all languages. It is further evident that in all questions relating to taxonomy and classification it is highly desirable that the scientific names be used.

International rules for nomenclature. In order that there be an international set of scientific names it is essential that there be an international agreement as to the rules which should govern their creation. Both of the great groups of biologists, the botanists and the zoologists, have met in numerous international congresses in which delegates were accredited by the great botanical and zoological societies, museums and educational institutions of the world. Codes of nomenclature designed to tell how names shall

be manufactured and used, and how to tell which of two or more names that have been used is correct, have been developed by each of these groups. These codes or lists of rules and recommendations are quite similar in essentials for botany and zoology, although they differ in some details.

The question arises: Are either or both of these codes satisfactory or adaptable to the use of bacteriologists. Three views have been expressed by various writers. Some few have suggested that the naming of bacteria cannot well conform to the approved international rules as their classification involves considerations not familiar to botanists and zoologists generally. The second group, also a very small one, has insisted that unicellular forms of life are neither plants or animals, but protists, and that taxonomy rules, etc., should be distinct for this group and coördinate with the corresponding rules for plants and for animals.

The third view, more commonly expressed, is that the bacteria are sufficiently closely related to the plants and animals, so that (in so far as they apply) the international agreements of the botanists (or zoologists), should be used as a basis for naming them.

International opinion on this topic was finally crystallized by resolutions adopted by the First International Congress of the International Society for Microbiology held in Paris in 1930 and by the Fifth International Botanical Congress held in Cambridge, England in the same year.

The resolutions unanimously adopted by the plenary session of the International Society for Microbiology were in part as follows:

"It is clearly recognized that the living forms with which the microbiologists concern themselves are in part plants, in part animals, and in part primitive. It is further recognized that *in so far as they may be applicable and appropriate* the nomenclatural codes agreed upon by International Congresses of Botany and Zoology should be followed in the naming of micro-organisms. Bearing in mind, however, the peculiarly independent course of development that bacteriology has taken in the past fifty years, and the elaboration of special descriptive criteria which bacteriologists have of necessity developed, it is the opinion of the International Society for Microbiology that the bacteria constitute a group for which special arrangements are necessary. Therefore the International Society for Microbiology has decided to con-

sider the subject of bacterial nomenclature as a part of its permanent program."

The International Society of Microbiologists established a permanent Nomenclature Committee to pass upon suggestions and to make recommendations. This committee is composed of members from all participating nations. Two secretaries were named, one (Dr. St. John-Brooks of the Lister Institute, London, England) to represent primarily medical and veterinary bacteriology, and one (Dr. R. S. Breed, New York State Agricultural Experiment Station, Geneva, New York, U. S. A.) to represent other phases of bacteriology.

The coöperation of the International Botanical Congress was solicited in the naming of this committee. The resolutions were approved by the Section on Bacteriology of the Botanical Congress and the Congress itself incorporated into the Botanical Code certain special provisions relating to the bacteria. It also specifically recognized the International Committee as the body to prepare recommendations relating to bacterial nomenclature.

It is apparent, therefore, that there has been international agreement in so far as this can be achieved that to the extent they are applicable bacteriologists in the naming of bacteria should follow the botanical or zoological codes, and that exceptions or new problems should be presented to the International Committee.

These rules are so important in determining the validity of bacterial names that the rules of the Botanical Code are included in somewhat abridged form in the section that follows this introduction. Any student who has occasion to name a new species or a new genus or determine the validity of a name should familiarize himself with these rules and recommendations.

An effort has been made in the present volume to use nomenclature in conformity to these rules.

Some general principles of nomenclature. Every student of bacteriology should be familiar with certain rules of nomenclature if he is to use names intelligently. If he wishes to correct names improperly used or if he desires the name new species there are additional rules which he must observe.

1. Each distinct kind of bacterium is called a species.

2. To each distinct species a name is given consisting usually of two Latin words, as *Bacillus subtilis.*

3. The first word is the name of the genus or group to which the organism belongs. It is a Latin (e.g. *Bacillus*) or less commonly a Greek (*Thiodictyon*) noun, and when used as a scientific generic name it must *always* be written with a capital letter. Although the genus name is regarded as a Latin word, it may be from some other language and treated as a Latin word. It may be masculine, feminine or neuter in gender. Some generic names in bacteriology which are Latin in origin are *Bacillus* (masculine), a small rod, *Cristispira* (feminine) a crested spiral; *Lactobacillus* (masculine) a milk bacillus; *Sarcina* (feminine) a packet or bundle. Many others are Latin transliterations of Greek words, such as *Micrococcus* (masculine) a small berry (sphere); *Bacterium* (neuter) a rod; *Aerobacter* (neuter) a gas (producing) rod; *Clostridium* (neuter) a spindle; *Corynebacterium* (neuter) a granular rod; *Actinomyces* (masculine) a ray thread (fungus). Other generic names have been given in honor of persons or places as *Beggiatoa* (feminine), *Borrelia* (feminine), *Eberthella* (feminine), *Pasteurella* (feminine), *Erwinia* (feminine), *Zopfius* (masculine).

4. The second word in the scientific name is a *specific* epithet. It is *not* capitalized except that certain authors capitalize species names derived from proper nouns.

It may be:

(a) An adjective modifying the noun, and indicating by its ending agreement with the generic name in gender, as *Bacterium albus* (white *Bacterium*), *Bacillus albus* (white *Bacillus*), *Sarcina alba* (white *Sarcina*), *Eberthella dispar* (the different *Eberthella*), *Bacterium variabile* (the variable *Bacterium*), *Brucella melitensis* (the maltese *Brucella*), *Bacillus teres* (the rounded *Bacillus*), *Bacillus graveolens* (sweet smelling *Bacillus*).

Typical adjectives

Masculine	Feminine	Neuter
albus	*alba*	*album*
niger	*nigra*	*nigrum*
tener	*tenera*	*tenerum*
acer	*acris*	*acre*
variabilis	*variabilis*	*variabile*
dispar	*dispar*	*dispar*
coccoides	*coccoides*	*coccoides*
aerogenes	*aerogenes*	*aerogenes*

(b) An adjective in the form of the present participle of a verb, as *Clostridium dissolvens* (the dissolving *Clostridium*, in the sense of the *Clostridium* which is able to dissolve), *Bacillus adhaerens* (the adhering *Bacillus*), *Acetobacter ascendens* (the climbing *Acetobacter*), *Bacillus esterificans* (the ester-producing *Bacillus*). The endings for participles used as adjectives are the same for all genders.

(c) A noun in the genitive (possessive) modifying the generic name. There is no necessary agreement in gender or number. Examples, *Clostridium welchii* (Welch's *Clostridium*), *Salmonella pullorum* (the *Salmonella* of chicks), *Streptococcus lactis* (the *Streptococcus* of milk), *Brucella abortus* (the *Brucella* of abortion), *Clostridium tetani* (the *Clostridium* of tetanus), *Diplococcus pneumoniae* (the *Diplococcus* of pneumonia), *Salmonella anatum* (the *Salmonella* of ducks).

(d) A noun in apposition, that is, an explanatory noun. This does not agree necessarily with the generic name in gender. This method of naming is relatively not common in bacteriology. Examples are *Actinomyces scabies* (the scurf or scab *Actinomyces*), *Bacillus lacticola* (the milk dweller-bacillus), *Bacillus radicola* (the root-dweller bacillus).

5. The author of the name is often indicated following the name of the species, as *Bacillus subtilis* Cohn. Sometimes a name is indicated also in parenthesis, as *Aurococcus aureus* (Rosenbach) Winslow and Rogers. This means that Rosenbach first named the species, giving it the name *aureus*, but placed it in another genus (*Staphylococcus*). Winslow and Rogers placed it in a new genus. It should be noted that the name of a person, following the name of an organism is frequently not the person who first discovered or described it, but the person who first gave it the name used. For example, *Clostridium welchii* (Migula) Holland was first described by Dr. Wm. H. Welch, but not named by him. It was named by Migula in honor of Dr. Welch, it was later placed in the genus *Clostridium* by Holland.

6. Sometimes species of bacteria are subdivided into varieties. These are likewise given Latin designations, and the entire name written as: *Streptococcus lactis* var. *maltigenes* (the lactic *Streptococcus* producing malt flavor).

Some principles of taxonomy. It is important further that the student of bacteriology recognize the meaning of certain terms used regularly in classifications.

(1) **Species** (plural **species**). A species of plant (or animal) is assumed above to be one kind of plant. But how much difference must exist between two cultures of bacteria before one is justified in terming them distinct kinds or species? There is no rule which can be laid down. It depends largely upon convenience and the more or less arbitrary decision of the student. As stated by Hitchcock (Descriptive Systematic Bacteriology, New York, 1925, p. 8): "The unit of classification is a coherent group of like individuals, called a species. The term is difficult to define with precision because a species is not a definite entity, but a taxonomic concept." Hucker and Pederson (New York Agric. Exper. Sta., Tech. Bull. 167, 1930, p. 39) state: "The difficulty met with among these lower forms in dividing them into well-defined groups has led many to question whether these small groups or 'species' are natural groups and whether such groups can be considered to be similar to 'species' among higher forms. However this may be, it is necessary to arrange bacteria as well as possible into groups or so-called 'species' for convenience in classification," and again (Hucker, New York Agric. Exper. Sta., Tech. Bull. 100, 1924, p. 29), "characters applicable to the differentiation of species must evidence a certain amount of constancy when studied over a large series of tests. Furthermore, characters adapted to the differentiation of larger natural groups or genera should, in addition to constancy, show some correlation with other constant characteristics. The presence of this relationship or correlation between characters for the division of genera indicates that the groupings are being made along natural rather than artificial lines."

Type culture. It is quite evident that when a new species of bacterium is described, it must include the particular culture from which the species description was made. This original culture is termed the type culture. We may develop a definition as follows: —A species of bacterium is the type culture or specimen together with all other cultures or specimens regarded by an investigator as sufficiently like the type (or sufficiently closely related to it) to be grouped with it. It is self-evident that different investigators

may not draw the same boundaries for a given species. This leads to some practical difficulties, but no better definition has been evolved.

There are certain special cases which require brief discussion.

(a) How should one designate the different stages in an organism that exhibits a growth cycle? There seems to be increasing evidence that certain bacteria show cycles in morphology which parallel to some degree those well known among the fungi. Such, for example, may well be the rough (R) and smooth (S) types described for many bacteria, possibly the filterable stages noted by many authors, the so-called G types, etc. It is evident that an adequate description of any species of bacterium should include a description of each of these stages in the cyclical development wherever such is proved to exist. In all other cases in botany and in zoology which involve growth stages or cycles one stage has been chosen and designated as the mature or adult or perfect stage. In ferns, for example, names and classifications are based largely upon the sporophytic generation, in insects upon the adult or imago, in the rusts upon the stage in which the teleutospores are produced. There has been no international agreement as to what stage should be thus designated for the bacteria. Beyond doubt, it would be the stage which is most easily cultured and studied in the laboratory, the stage with which we are best acquainted in the laboratory. It might easily happen in bacteria (as it has with fungi) that two different stages of the life cycle of single species have been described and named as separate species. When the mistake has been discovered, the name given to the mature or perfect stage is the one that is accepted. In general the descriptions given in the present volume are those which may be regarded as belonging to the perfect stage. Unfortunately it is not yet possible accurately to group the stages in many of the bacteria that have definite growth cycles. In future editions it is hoped that this lack may be corrected, and descriptions of the variants or stages included.

It is desirable frequently to designate the stage with which one is working. This may be done by some conventional symbol, as S (smooth type), G, filterable stage, etc.

(b) How should one designate variants which differ in some

minor respects from the type, but which do not constitute growth stages? For example, the species *Bacillus subtilis* normally produces endospores. Suppose that an asporogenous race is derived from such, agreeing with the parent culture in all respects, but showing no tendency to revert to spore production. What such an organism should be called is a matter of judgment. It might frequently be designated as an asporogenous strain, or more technically if one desires as a variety. It might be termed, for example, *Bacillus subtilis* var. *asporus*. In other cases such expressions as *Diplococcus pneumoniae* type I, or the Rawlin's strain of the typhoid bacillus may be used.

(2) **Genus** (plural **genera**). A genus is a group of related species. In some cases a genus may include only a single species (is said to be *monotypic*), in most cases several to many species are included in a genus. The question asked above may be paraphrased. How close must be the resemblances (how close the relationships) among the species of a group to entitle them to inclusion in the same genus? In other words, how is it possible to delimit accurately the boundaries of a genus? This is a matter on which there is no agreement, and probably can be none. Much of the confusion in modern bacteriological terminology is to be attributed to this fact. Nevertheless, in course of time experience tends to delimit many genera with reasonable accuracy. As stated by Hitchcock (Descriptive Systematic Botany, New York, 1925, p. 9): "Convenience may play a rôle in determining generic lines. Extremely large groups may be broken up on the basis of differences of smaller degree not common to a group of closely allied species, than if the group consisted of a few species. In general, the botanist, in delimiting genera, keeps in mind two important requirements, that of showing natural affinities and that of aiding correct identification." However, a genus may be defined helpfully in another way. The first species described as belonging to a genus is designated as the *type* species. A genus may be defined then, as including this type species together with such other species as the investigator (or taxonomist) regards as sufficiently closely related. It is apparent that some authors may draw the lines narrowly, others broadly. Some authors, for example recognize only two genera of rod-shaped bacteria, one for

those without endospores (*Bacterium*), and one for those producing endospores (*Bacillus*). These genera thus defined are very large, each containing hundreds, perhaps thousands, of species. Other students break up these large genera into many smaller ones. There is not much point to the question as to which is right and which is wrong. A better question is, which is the more convenient, better represents relationships, better facilitates diagnosis and proves most useful. As organisms become better known, it may be possible through the agency of the International Committee on Nomenclature to reach agreements where lack of agreement leads to serious confusion or misunderstanding.

(3) **Family.** A family in taxonomy is a group of related genera. In general the name of the family is made from the name of the genus chosen as the type genus of the family, by affixing the suffix *-aceae* to the root. The word is regarded as plural. Among bacterial families commonly recognized are *Bacillaceae, Bacteriaceae, Coccaceae, Spirochaetaceae, Actinomycetaceae.*

(4) **Order.** An order is a group of related families. It is named usually (not always) by substituting the suffix *-ales* for *-aceae* in the name of the type family. Among ordinal names that have been used in bacteriology are *Actinomycetales, Spirochaetales, Eubacteriales.*

(5) **Class.** A class is a group of related orders. In this treatise it is considered that the bacteria constitute a class of the plant kingdom, and is named *Schizomycetes.*

(6) **Other categories.** Other *categories* or *ranks* of names are used for higher groups. Sometimes families are divided into subfamilies, these into tribes, these into subtribes, and these finally into genera.

How to identify an organism by name. One of the main purposes of a manual of determinative bacteriology is to facilitate the finding of the correct scientific name of a bacterium. Such is the purpose of this volume. It is well, however, to note some of the reasons why this result, the identification of an unknown culture, may not eventuate. Among these reasons the following may be listed:

(1) The unknown organism awaiting identification by the investigator may easily be one which has never been named, or

perhaps adequately described. For the most part there has been little effort on the part of bacteriologists to describe or name bacteria except as they have been found to have some economic significance or possess some striking or unusual characteristics. It is quite probable that there are many times as many species of bacteria undescribed and named as have been described. Such undescribed species are all about us. It is not surprising, therefore, if one frequently encounters undescribed species. When such unnamed species are encountered, particularly if they are of economic importance or are related to such forms, it is highly desirable that they should be described, named and the results published and made accessible.

(2) The unknown organism may have been described and named in some publications, but the description and name have been overlooked in the preparation of the manual. Perhaps the description has been so inadequate or incomplete that it has not been possible to place it in the classification. It should be noted that the number of species that have been described is so great that no one individual can know all the species. Progress in classification comes about largely as the result of the work of specialists in particular groups. For example, Ford made a study of all of the aerobic spore-bearing bacteria which he had secured from various sources. He studied also the descriptions of such bacteria in the literature, and then monographed the group. Similar studies on other groups have resulted in more or less complete monographs. Such, for example, are the monographs on the intestinal group by Welden and Levine, of the acetic bacteria by Hoyer and Visser 't Hooft, of the cocci by Hucker, of the pathogenic spore-bearing anaerobes by the English Commission, by Weinberg, and by others, of the red rod shaped bacteria by Hefferan and by Breed, of the *Actinomycetes* by Waksman and by Lieske, on the root nodule bacteria of legumes by Fred and his co-workers, etc. Unfortunately most groups of bacteria have not thus been monographed. It is evidently the function of a manual such as this to draw largely upon the work of the monographers, and to supplement as far as possible by less satisfactory consideration of the unmonographed groups.

It is clear that because an organism cannot be identified from

this text is not proof that it has not been described and named. The species most closely related may be determined, then the literature searched carefully for species described still more closely related or perhaps one identical.

(3) It is possible, of course, that an error has been made in the selection of the correct name. It is desirable that users of these keys and descriptions should be familiar with the rules governing the correct choice of names, and make suitable corrections where needed.

Steps in determining the name of an organism. The steps in the identification of an unknown organism are usually the following:

(1) Preparation of an adequate description of the organism.

(2) Knowledge of construction and use of keys.

(3) Determination of order, family and genus by use of key.

These steps will be considered in order.

Preparation of description of organism. Before attempting to determine the name of an "unknown" organism an adequate description is essential. Just what characteristics must be emphasized depends upon the group in which the organism falls. It is desirable that the knowledge of the characters of the unknown be as complete as possible.

Use and construction of keys. An exceptionally clear and satisfactory discussion of the making and use of keys and synopses is given by Hitchcock (Descriptive Systematic Botany, New York, 1925, p. 104). Anyone planning to monograph a group is advised to read this. He states: "A key is an orderly arrangement of a series of contrasting or directly comparable statements, by which groups of the same category may be distinguished and indicated or identified," and "A key is primarily a mechanical device by which one may arrive at the name of the ultimate member of the group."

In the keys used in this manual, there is an effort to bring out systematic relationships, so-called *natural keys.* In general the keys used are *dichotomous,* that is, the successive divisions are in twos, differentiation being into two contrasted groups.

BACTERIOLOGICAL CODE

At the Paris Congress in 1930, the International Society of Microbiology voted to follow the rules of nomenclature agreed upon by International Congresses of Botany and Zoology *"in so far as they may be applicable and appropriate."* The following rules are taken from the International Rules of Nomenclature adopted by the International Botanical Congresses of Vienna, 1903, and of Brussells, 1910 (Gustav Fischer, Jena, 1912). A new edition of the International Rules of Botanical Nomenclature is to be issued as a result of changes made at the International Botanical Congress held in Cambridge, England in 1930. This is not yet available but the most important of the changes that apply to bacteriological nomenclature are noted below (Chap. III, Sect. 2, Art. 19, Chap. III, Sect. 4, Art. 36).

Chap. I, Art. 7. Scientific names are in Latin for all groups.

Chap. II, Art. 10. Every individual plant belongs to a species (species), every species to a genus (genus), every genus to a family (familia), every family to an order (ordo), every order to a class (clasis), every class to a division (diviso).

Chap. III, Sect. 1, Art. 15. Each natural group of plants can bear in science only one valid designation, namely the oldest, provided that it is in conformity with the rules of Nomenclature and the conditions laid down in articles 19 and 20 of Section 2.

Chap. III, Sect. 2, Art. 19. Botanical nomenclature begins for the different groups of plants (recent and fossil) at the following dates:

Note: The starting point of the nomenclature of *Schizomycetes* (Bacteria) was left for the consideration of the Congress at London which was to have been held in 1915. When this Congress convened at Cambridge in 1930, it was decided that bacteriological nomenclature should begin with Linnaeus, that is all bacteriological literature should be included.

Chap. III, Sect. 2, Art. 20. However, to avoid disadvantageous changes in the nomenclature of genera by the strict application of the rules of nomenclature, and especially of the principle of priority in starting from dates given in Article 19, the rules provide a list of names which must be retained in all cases. These names are by preference those which have come into general use in the fifty years following their publication, or which have been used in monographs and important floristic works up to 1890.

Chap. III, Sect. 3, Rec. III. Orders are designated preferably by the name of one of the principal families, with the ending "*ales.*"

Chap. III, Sect. 3, Art. 21. Families (familiae) are designated by the name of one of their genera or ancient generic names with the ending "*aceae.*"

Chap. III, Sect. 3, Art. 23. Names of subfamilies (subfamiliae) are taken from the name of one of the genera of the group with the ending "*oideae.*" The same holds for the tribes (tribus) with the ending *eae* and for subtribes (subtribus) with the ending *inae.*

Chap. III, Sect. 3, Art. 24. Genera receive names, substantives (or adjectives used as substantives) in the singular number and written with a capital letter which may be compared with our own family names. These names may be taken from any source whatever, and may even be composed in an absolutely arbitrary manner.

Chap. III, Sect. 3, Art. 25, Rec. V. Botanists who are publishing generic names show judgment and taste by attending to the following recommendations:

A. Not to make names very long or difficult to pronounce.

B. Not to use again a name that has already been used and has lapsed into synonymy (homonym).

C. Not to dedicate genera to persons who are in all respects strangers to Botany or at least to natural science, nor to persons quite unknown.

D. Not to take names from barbarous tongues, unless those names are frequently quoted in books of travel, and have an agreeable form that is readily adapted to the Latin tongue and to the tongues of civilized countries.

E. To recall if possible by the formation or ending of the name, the affinities or the analogies of the genus.

F. To avoid adjectives used as nouns.

G. Not to give a genus a name whose form is rather that of a subgenus or section (e.g. *Eusideroxylon* a name given to a genus of *Lauraceae,* which, however, being valid, cannot be changed).

H. Not to make names by the combinationof two languages (nomina hybrida).

Chap. III, Sect. 3, Art. 26. All species, even those that singly constitute a genus, are designated by the name of the genus to which they belong, followed by a name (or epithet) termed specific, usually of the nature of an adjective (forming a combination of two names, a binomial, or binary name).

Chap. III, Sect. 3, Art. 26, Rec. VIII. The specific name should in general, give some indication of the appearance, the characters, the origin, the history or the properties of the species. If taken from the name of a person it usually is the name of the one who discovered or described it, or was in some way concerned with it.

Chap. III, Sect. 3, Rec. X. Specific names begin with a small letter except those which are taken from names of persons (substantives

or adjectives) or those which are taken from generic names (substantives or adjectives).

Note: Botanical and zoological usage differ in regard to the use of capitals for the first letter of specific names that are taken from the names of persons or from generic names. The custom followed by zoologists of beginning all specific names with a small letter has been followed throughout the MANUAL.

Chap. III, Sect. 3, Rec. XIV. In forming specific names, botanists will do well to note the following recommendations:

a. Avoid very long names and those which are difficult to pronounce.

b. Avoid names which express a character common to all or nearly all of the species of the genus.

c. Avoid names taken from little known or very restricted localities, unless the species be very local.

d. Avoid, in the same genus, names which are very much alike, especially those which differ only in their last letters.

e. Adopt unpublished names found in travellers' notes, and herbaria attributing them to the authors concerned, only when those concerned have approved the publication.

f. Avoid names which have been used before in the genus, or in closely allied genus, and which have lapsed into synonymy (homonyms).

g. Do not name a species after a person who has neither discovered nor described nor figured, nor in any way studied it.

h. Avoid specific names formed of two words.

i. Avoid names which have the same meaning as the generic name.

Chap. III, Sect. 4, Art. 35. Publication is effected by the sale or public distribution of printed matter or indelible autographs. Communication of new names at a public meeting, or the placing of names in collections or gardens open to the public, do not constitute publications.

Chap. III, Sect. 4, Art. 36. On and after January 1, 1908, the publication of names of new groups will be valid only when they are accompanied by a Latin diagnosis.

Note: Certain groups, among them being *Schizomycetes* were exempted from the provisions of this rule at the Congress held at Cambridge in 1930.

Chap. III, Sect. 4, Art. 37. A species or a subdivision of a species, announced in a work, with a complete specific or varietal name, but without diagnosis or reference to a former description under another name is not valid. Citation in synonymy or incidental mention of a name is not effective publication.

Chap. III, Sect. 4, Art. 38. A genus or any other group of higher rank than a species named or announced without being characterized conformably to Article 37 cannot be regarded as effectively published (nomen nudum).

Chap. III, Sect. 5, Art. 40. For the indication of the name or names of a group to be accurate and complete and in order that the date may be readily verified it is necessary to quote the author who first published the name or combination of names in question.

Chap. III, Sect. 5, Art. 41. An alteration of the constituent characters or of the circumscription of a group does not warrant the quotation of another author than the one who first published the name or combination of names.

Chap. III, Sect. 6, Art. 44. A change of characters or a revision which involves the exclusion of certain elements of a group or the addition of new elements does not warrant a change of the name or names of a group except in cases provided for in Art. 51.

Art. 45. When a genus is divided into two or more genera, the name must be kept and given to one of the principal *divisions,* either to the division containing the *type* of the original group or to the division containing the largest number of species.

Art. 46. When two or more groups of the same nature are united, the name of the oldest is retained.

Art. 47. When a species or a subdivision of a species is divided into two or more groups of the same nature, if one of the two forms was distinguished or described earlier than the other, the name is retained for that form.

Art. 48. When a subgenus or section or species is moved into another genus, when a variety or other division of a species is moved into another species, retaining there the same rank, the original name of the subgenus or section, the first specific epithet, or the original name of the division of the species must be retained or must be re-established, unless in the new position there exists one of the obstacles indicated in the articles of Section 7.

Art. 49. When a tribe becomes a family, a subgenus or a section becomes a genus, a subdivision of a species becomes a species, or the reverse of these changes takes place, and speaking generally, when a group changes its rank, the earliest name (or combination of names) received by the group in its new position must be regarded as valid, if it is in conformity with the rules, unless there exist any of the obstacles indicated in the articles of Section 7.

Art. 50. No one is authorized to reject, change or modify a name (or combination of names) because it is badly chosen, or disagreeable, or another is preferable or better known, or because of the existence of an earlier homonym which is universally regarded as non-valid, or for any other motive, either contestable or of little import. (See also Art. 57.)

Art. 51. Everyone should refuse to admit a name in the following cases:

1. When the name is applied in the plant kingdom to a group which has an earlier valid name.

2. When it duplicates the name of a class, order, family or genus, or a subdivision or species of the same genus, or a subdivision of the same species.

3. When it is based on a monstrosity.

4. When the group which it designates embraces elements altogether incoherent or when it becomes a permanent source of confusion or error.

5. When it is contrary to the rules of sections 4 and 6.

Art. 53. When a species is moved from one genus into another, its specific epithet must be changed if it is already borne by a valid species of the genus. The same rule applies to other transferred groups.

Art. 56. In the cases foreseen in articles 51 and 53, the name to be rejected or changed is replaced by the oldest valid name in the group in question, and in default of such a one, a new name must be made.

Chap. IV, Art. 58. The rules of botanical nomenclature can only be modified by competent persons at an international congress convened for the express purpose.

CLASS SCHIZOMYCETES NÄGELI, 1857.

Synonyms: *Bacteria* Cohn, Beitr. Biol. d. Pflanzen, *1*, Heft 1, 1872, 136; *Bacteriaceae* Cohn, *ibid.*, 237; *Bacteriales* Clements (as an ordinal name), The Genera of Fungi, Minneapolis, 1909, 8; *Schizomycetaceae* De Toni and Trevisan, Saccardo, Sylloge Fungorum, *8*, 1889, 923; *Schizomycetacea* Castellani and Chalmers, Manual of Tropical Medicine, 3rd. ed., 1919, 924; *Mychota* Enderlein, Bakteriencyclogenie, 1924, 236.

Typically unicellular plants, cells usually small and relatively primitive in organization. The cells are of many shapes, spherical, cylindrical, spiral or filamentous; cells often united into groups, families or filaments; occasionally in the latter showing some differentiation among the cells, simulating the organization seen in certain of the blue-green, filamentous algae. Multiplication typically by cell fission. Endospores are formed by some species of the *Eubacteriales*, conidia by some of the filamentous forms. Chlorophyll is produced by none of the bacteria (with the possible exception of a single genus). Many forms produce pigments of other types. The cells may be motile by means of flagella; some of the forms intergrading with the protozoa are flexuous, a few filamentous forms (as *Beggiatoa*) show oscillatory movement similar to that of certain blue-green algae (as *Oscillatoria*).

Key to the orders of the class Schizomycetes.

1. Simple and undifferentiated forms, without true branching. Occur as spheres, short or long straight rods, or as curved rods. Motile or non-motile. Endospore formation occurs in some species. Some species form pigment. Some species store reserve materials as volutin, glycogen or fat. Sulfur and/or iron are not stored as visible particles.

   Order I. *Eubacteriales*, p. 29.

2. Specialized or differentiated forms, occurring as spheres, short or long straight rods, short or long spirals, or filamentous forms. Some of the longer forms occasionally show branching. Endospores are not formed. Some of the orders show segmentation of the terminal ends of filaments into short, specialized cells, conidia, which are usually more resistant to external agencies than are the vegetative forms. Many forms produce pigment, others contain bacteriopurpurin or bacteriochlorin or both. Some forms show definite granules of sulfur within the cytoplasm.
   a. Plant-like; bacterial, not protozoal.
   b. Mold-like.

Cells rod-shaped or filamentous with decided tendency to true branching. Many pathogenic forms show distinct enlargement of the ends when growing in the animal body or even in culture media. Non-motile. Sulfur granules or bacteriopurpurin absent. Conidia may be formed.

Order II. *Actinomycetales*, p. 495.

bb. Not mold-like.

c. Sheathed.

Filamentous forms, alga-like, typically water forms. May show false branching. Filaments enclosed in a sheath which is frequently impregnated with iron. Conidia may be developed. Sulfur granules or bacteriopurpurin absent.

Order III. *Chlamydobacteriales*, p. 563.

cc. Not sheathed.

d. Sulfur bacteria.

Cells spherical, short or long straight rods, short spirals or filaments. Spores rarely or never formed. Conidia not formed. Sheath absent. Cells contain sulfur granules, bacteriopurpurin and bacteriochlorin.

Order IV. *Thiobacteriales*, p. 567.

dd. Slime mold-like.

Motile, rod-like forms secreting a gelatinous base and forming a pseudoplasmodium-like aggregation, later developing into a cyst-producing, resting stage. Endospores are not formed. Conidia absent. Sulfur granules and bacteriopurpurin absent. Most of the species form pigment.

Order V. *Myxobacteriales*, p. 587.

aa. Protozoan-like.

Cells slender spirals, flexuous. Endospores not formed. Multiplication apparently by both transverse and longitudinal division.

Order VI. *Spirochaetales*, p. 617.

ORDER I. EUBACTERIALES BUCHANAN, 1917.

Key to the families of the order **Eubacteriales.**

1. Organisms usually rod-shaped, occasionally spherical, or nearly so. Endospores not ordinarily formed. May use in their metabolism carbon, hydrogen, sulphur, or nitrogen, or simple compounds of these. May oxidize ethyl alcohol to acetic acid.

Family I. *Nitrobacteriaceae*, p. 30.

2. Not securing growth energy as under I. Utilize organic matter.

a. Cells spherical.

Cells occur singly, in pairs, tetrads, packets, chains, or irregular masses. A few species are motile. Endospores are not formed. Pigment is formed by some species. Generally grow on ordinary culture media.

Family II. *Coccaceae*, p. 47.

aa. Cells not spherical.

b. Cells spiral.

Cells occur as short, curved rods or in spiral chains. Not flexuous. Endospores not produced. Many species are motile, having polar flagella. Grow well on ordinary culture media.

Family III. *Spirillaceae*, p. 109.

bb. Cells straight rods.

c. Endospores not formed.

Cells motile or non-motile. Endospores are absent. Many species form pigment. Bacteriopurpurin and bacteriochlorin absent. Sulphur granules absent. Require complex organic substances for food. Can not utilize simple compounds of carbon, sulfur, nitrogen or hydrogen as food, or at least only to a limited extent. Carbohydrates may be utilized with the formation of acid or acid and gas. Some species hydrolyze starch.

Family IV. *Bacteriaceae*, p. 122.

cc. Endospores formed.

Cells motile or non-motile. Generally utilize complex protein substances as food. Simple sugars and starch are utilized by many species.

Family V. *Bacillaceae*, p. 414.

FAMILY I. NITROBACTERIACEAE BUCHANAN, 1917.

Organisms usually rod-shaped, sometimes nearly spherical. Motile or non-motile. Branched involution forms are produced. Endospores not ordinarily formed. Capable of metabolizing carbon, hydrogen, sulfur or nitrogen or of simple compounds of these, or of oxidizing ethyl alcohol to acetic acid. Non-parasitic (except in genus *Rhizobium*), usually water or earth forms.

Key to the tribes and genera of the family Nitrobacteriaceae.

1. Organisms oxidize simple inorganic compounds of carbon, hydrogen, sulfur or nitrogen, or oxidize ethyl alcohol to acetic acid.

Tribe I. *Nitrobacterieae*, p. 31.

a. Cells capable of securing growth energy by the oxidation of hydrogen to form water.

Genus I. *Hydrogenomonas*, p. 31.

b. Cells oxidize methane to form CO_2 and water.

Genus II. *Methanomonas*, p. 33.

c. Cells oxidize CO to form CO_2.

Genus III. *Carboxydomonas*, p. 33.

d. Cells oxidize ammonia to form nitrites.

Genus IV. *Nitrosomonas*, p. 34.
Genus V. *Nitrosococcus*, p. 35.

e. Cells oxidize nitrites to nitrates.
Genus VI. *Nitrobacter*, p. 35.
f. Cells oxidize alcohol to form acetic acid.
Genus VII. *Acetobacter*, p. 37.
g. Cells oxidize elementary sulfur and compounds of sulfur.
Genus VIII. *Thiobacillus*, p. 41.
2. Organisms capable of fixing free nitrogen of the air.
Tribe II. *Azotobacterieae*, p. 42.
a. Cells capable of fixing free atmospheric nitrogen when growing in solutions of carbohydrates.
Genus IX. *Azotobacter*, p. 42.
b. Cells capable of fixing free nitrogen when growing symbiotically on the roots of *Leguminosae*.
Genus X. *Rhizobium*, p. 44.

TRIBE I. NITROBACTERIEAE COMMITTEE S. A. B., 1920.

Organisms deriving their life energy from oxidation of simple compounds of carbon or nitrogen (or alcohol).

Genus I. Hydrogenomonas *Orla-Jensen, 1909.*

Short rods capable of growing in the absence of organic matter, and securing growth energy by the oxidation of hydrogen, forming water.

The type species is *Hydrogenomonas pantotropha* (Kaserer) Orla-Jensen.

1. **Hydrogenomonas pantotropha** (Kaserer) Orla-Jensen. (*Bacillus pantotrophus* Kaserer, Cent. f. Bakt., II Abt., *16*, 1906, 681; Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1908, 305.)

Rods: 0.4 to 0.5 by 1.2 to 1.5 microns with rounded ends, occurring singly, in pairs and in chains. Encapsulated. Actively motile by means of a single polar flagellum.

Gelatin colonies: Yellow, smooth, rarely concentrically ringed or greenish.

Gelatin stab: No liquefaction.

Agar colonies: Same as on gelatin, greenish.

Agar slant: Smooth yellow growth, occasionally greenish, often tough, slimy.

Broth: Turbid, with slimy sediment and sometimes with pellicle formation.

Litmus milk: No coagulation. A yellow pellicle forms. Medium becomes slimy and assumes a flesh color.

Potato: Smooth, soft, yellow, glistening.

Oxidizes hydrogen to form water by first catalytically reducing CO_2 to produce formaldehyde, the latter serving as food.

Indol is not formed.

H_2S is not formed.
Nitrates are not reduced.
Does not act on carbohydrates.
Aerobic.
Optimum temperature 30°C.
Habitat: Soil.

2. **Hydrogenomonas pycnotica** (Ruhland and Grohmann) Bergey et al. (*Bacillus pycnoticus* Ruhland and Grohmann, Cent. f. Bakt., II Abt., *61*, 1924, 261; Manual, 3rd ed., 1930, 34.)

Rods with rounded ends, 1.0 by 1.5 to 4.0 microns occurring singly and in chains. Globular forms are also seen. Motile with peritrichous flagella. Spores are formed. Gram negative.

Gelatin colonies.
Gelatin stab: Liquefied.
Agar colonies: Small, circular, grayish-brown.
Agar slant: Dirty-white, raised streak.
Broth: Turbid, with pellicle.
Litmus milk.
Potato.
Indol.
Nitrates.
Oxidize hydrogen to water.
Aerobic.
Optimum temperature 20°C.
Habitat: Soil.

3. **Hydrogenomonas vitrea** Niklewski. (Cent. f. Bakt., II Abt., *20*, 1907–08, 469; Zeitschr. f. wissensch. Botanik, *48*, 1910, 113; Abst. in Cent. f. Bakt., II Abt., *28*, 1910, 514; Jour. Bact., *5*, 1920, 201.)

Rods: 2.0 microns in length, cells adhering to each other. Motility not observed.

Agar colonies: Soft, folded, transparent, with slight fluorescence, and yellow center. Do not develop readily beneath the surface of medium.

Liquid media: Pellicle, adherent to wall of tube.

Oxidize hydrogen to water.

Microaerophilic, growing in an atmosphere of low oxygen tension, not exceeding 8 per cent.

Can thrive heterotrophically, but not so well as *Hydrogenomonas flava*.

Habitat: Soil.

4. **Hydrogenomonas flava** Niklewski. (Cent. f. Bakt., II Abt., *20*, 1908, 469; Zeitschr. wiss. Bot., *48*, 1910, 113; Jour. Bact., *5*, 1920, 201.)

Rods: 1.5 microns in length. Motility not observed in agar culture.

Agar colonies: Small, smooth, yellow, shining, adhering to medium. Develop well below surface of medium, but growth is paler.

Liquid media: No pellicle formation. Thick, flat cheesy masses are formed.

Oxidize hydrogen to water.

Microaerophilic, growing in an atmosphere of low oxygen tension, not exceeding 8 per cent.

Thrives well heterotrophically.

Habitat: Soil.

Genus II. Methanomonas *Orla-Jensen, 1909.*

Monotrichous short rods capable of growing in the absence of organic matter and securing growth energy by the oxidation of methane, forming CO_2 and water.

The type species is *Methanomonas methanica* (Söhngen) Orla-Jensen.

1. **Methanomonas methanica** (Söhngen) Orla-Jensen. (*Bacillus methanicus* Söhngen, Cent. f. Bakt., II Abt., *15*, 1906, 513; Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1908, 305.)

Short rods: 1.5 to 2.0 by 2.0 to 3.0 microns, motile in young cultures by means of a single flagellum. In older cultures nearly spherical. Can be cultivated in an atmosphere composed of one part CH_4 and two parts air on washed agar containing the necessary inorganic salts. The growth is membranous.

At the end of two weeks, the air of the flasks consists of the following:

CH_4	0
CO_2	78
O_2	172

Habitat: Soil.

Genus III. Carboxydomonas *Orla-Jensen, 1909.*

Autotrophic rod-shaped cells capable of securing growth energy by the oxidation of CO, forming CO_2.

The type species is *Carboxydomonas oligocarbophila* (Beijerinck and van Delden) Orla-Jensen.

1. **Carboxydomonas oligocarbophila** (Beijerinck and van Delden) Orla-Jensen. (*Bacillus oligocarbophilus* Beijerinck and van Delden, Cent. f. Bakt., II Abt., *10*, 1903, 33; Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1908, 305.)

Very small, colorless rods united into irregular masses by a slimy substance, 0.5 by 0.7 to 1.0 microns. Non-motile. There is but little cytoplasm within the slimy cellulose wall of the cells.

Growth occurs in culture fluids free from organic matter and on washed agar containing the necessary inorganic salts.

No growth occurs in media with carbonaceous materials.

The organism forms a thick, slimy film on fluid media.

The organism utilizes CO as food, and in symbiosis with other bacteria, also oxidizes hydrogen to water by catalytically reducing CO_2 to CO, using the latter as food, again oxidizing it to CO_2.

Grows best in the dark.
Optimum temperature 25°C.
Habitat: Soil.

Genus IV. Nitrosomonas *Winogradsky, 1892.*

Cells rod-shaped, motile, possessing polar flagella. Capable of securing growth energy by the oxidation of ammonia to nitrites. Growth on media containing organic matter scanty or absent.

The type species is *Nitrosomonas europaea* Winogradsky.

1. **Nitrosomonas europaea** Winogradsky. (Arch. Sci. biol., St. Petersburg, *1*, 1892, 1.)

Rods: 0.9 to 1.0 by 1.1 to 1.8 microns occurring singly, rarely in chains of three to four. Possess a single polar flagellum 3 to 4 times the length of the rods, or rarely one at either end.

Grow readily in a fluid medium without organic matter, and containing ammonium sulphate, potassium phosphate and basic carbonate of magnesium. The organisms unite in zoogleal masses around the particles of magnesium carbonate in the bottom of the flask.

Small, compact, sharply defined colonies brownish in color, form on silicate medium.

Ammonium salts are converted into nitrites.

Habitat: Soil.

2. **Nitrosomonas javanensis** Winogradsky. (Arch. Sci. biol., St. Petersburg, *1*, 1892, 1.)

Small rods, ovoid, 0.2 to 0.5 micron in length. Possess a polar flagellum 20 times as long as the rods.

In fluid inorganic media, minute flocculi or scales are formed, adherent to the walls of the flask, the fluid remaining clear.

On silicate medium the colonies are circular to elliptical.

Forms nitrites.

Habitat: Soil.

3. **Nitrosomonas groningensis** Sack. (Cent. f. Bakt., II Abt., *64*, 1925, 34.)

Rods: 0.4 by 0.6 micron. Non-motile. Gram negative.
Gelatin colonies: Small, circular, colorless, glistening.
Gelatin stab: Slow liquefaction.
Agar colonies: Small, circular, colorless, glistening.
Silica plate colonies: Circular, colorless, compact.
Broth: Turbid.
Litmus milk: Strongly alkaline.
Potato: Small colorless colonies.
Indol not formed.
In the absence of oxygen nitrates are reduced to nitrites.
Nitrite is formed in peptone solution containing $(NH_4)_2SO_4$.

Cellulose is slowly attacked.

Carbon is derived from CO_2, dextrose, levulose, maltose, sucrose and asparagin.

Aerobic.

Optimum temperature 20°C.

Habitat: Soil.

Genus V. **Nitrosococcus** *Winogradsky, 1892.*

Large spherical organisms, showing no growth on ordinary culture media. Change ammonia to nitrites in soil and in suitable culture media.

The type species is *Nitrosococcus nitrosus* (Migula) Bergey et al.

I. **Nitrosococcus nitrosus** (Migula) Bergey et al.

Synonyms: *Nitrosococcus* Winogradsky, Arch. de sci. biol. St. Petersbourg, 1892, 121; Ann. de l'Institut Pasteur, *5*, 1891, 577; *Micrococcus nitrosus* (Winogradsky) Migula, System der Bakterien, 1900, 194.

Large spheres, 1.5 to 1.7 microns in size, with thick cell membrane. Motility could not be demonstrated.

Silicate medium: Large, shiny colonies, clear to yellowish, granular

Changes nitrites to nitrates.

Aerobic.

Optimum temperature 20–25°C.

Habitat: Soil.

Genus VI. **Nitrobacter** *Winogradsky, 1892.*

Cells rod-shaped, non-motile, not growing readily on organic media, oxidizing nitrites to nitrates.

The type species is *Nitrobacter winogradskyi* Buchanan.

1. **Nitrobacter winogradskyi** Buchanan. (*Nitrobacter*, Winogradsky, Arch. Sci. biol. St. Petersburg, *1*, 1892, 87; Buchanan, Jour. of Bact., *3*, 1918, 180.)

Short, non-motile rods with gelatinous membrane, 0.6 to 0.8 by 1.0 to 1.2 microns.

Can be cultivated on media free of organic matter.

Washed agar colonies: In 7 to 10 days very small, light brown, circular to irregular colonies, becoming darker.

Silicic acid gel colonies: Colonies smaller but more dense than on washed agar.

Washed agar slant: In 7 to 10 days scanty, grayish streak.

Mineral broth: After 10 days flocculent sediment.

Nitrites are oxidized to nitrates.

Aerobic.

Optimum temperature 25° to 28°C.

Habitat: Soil.

2. **Nitrobacter punctatum** Sack. (Cent. f. Bakt., II Abt., *62*, 1924, 20.)
Large rods: 2.0 by 3.0 microns long. Non-motile. Gram positive.
Gelatin colonies: Circular, white.
Gelatin stab: Slow liquefaction.
Nitrite agar colonies: Circular, white, granular, undulate margin.
Broth: No turbidity.
Nitrite litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrate formed from nitrite.
H_2S not formed.
Cellulose is hydrolyzed.
Can obtain carbon from carbon dioxid, dextrose, levulose, lactose, sucrose, mannitol, cellulose but not from carbonates.
Aerobic.
Optimum temperature 20°C.
Habitat: Soil.

3. **Nitrobacter flavum** Sack. (Cent. f. Bakt., II Abt., *62*, 1924, 20.)
Rods: 0.5 by 2.0 microns. Non-motile. Gram negative.
Gelatin colonies.
Gelatin stab: Yellow surface growth. No liquefaction.
Nitrite agar colonies: Small, circular, yellow.
Agar slant: Filiform, yellow streak.
Broth: No turbidity.
Nitrite litmus milk: Unchanged.
Potato: Thick, creamy layer.
Indol formed.
Nitrate formed from nitrite.
H_2S not formed.
Cellulose is hydrolyzed.
Can obtain carbon from carbon dioxid, dextrose, levulose, lactose, sucrose, mannitol, cellulose but not from carbonates.
Aerobic.
Optimum temperature 20°C.
Habitat: Soil.

4. **Nitrobacter opacum** Sack. (Cent. f. Bakt., II Abt., *62*, 1924, 21.)
Rods: 0.2 by 2.0 microns. Non-motile. Gram positive.
Gelatin colonies: Circular, orange-colored.
Gelatin stab: Liquefied.
Nitrite agar colonies: Circular, orange-colored.
Broth: Turbid with orange-colored sediment.
Nitrite litmus milk: Unchanged.
Potato: Thick, moist, reddish-orange layer.
Indol not formed.
Nitrate formed from nitrite.

H_2S not formed.

Cellulose is hydrolyzed.

Can obtain carbon from carbon dioxid, dextrose, levulose, lactose, sucrose, mannitol and cellulose but not from carbonates.

Aerobic.

Optimum temperature 20°C.

Habitat: Soil.

Genus VII. **Acetobacter** *Beijerinck, 1901.*

Cells rod-shaped, frequently in chains, motile or non-motile. Usually grow on the surface of alcoholic solutions as obligate aerobes, securing growth energy by the oxidation of alcohol to acetic acid. Also capable of utilizing certain other carbonaceous compounds, as sugar and acetic acid. Elongated, filamentous, club-shaped, swollen and even branched cells may occur as involution forms.

The type species is *Acetobacter pasteurianum* (Hansen) Beijerinck.

Key to the species of genus **Acetobacter**

A. Motility generally absent
- a. Form acetic acid in dextrose, ethyl and propyl alcohol, and in glycol.
  1. *Acetobacter pasteurianum.*
  2. *Acetobacter aceti.*
  3. *Acetobacter kützingianum.*
  4. *Acetobacter lindneri.*
- aa. Form acetic acid in dextrose, galactose, ethyl and propyl alcohol, and glycol.
  5. *Acetobacter acetosum.*
- aaa. Form acetic acid in dextrose, ethyl and propyl alcohol, glycol, and in sucrose.
  6. *Acetobacter xylinum.*
  7. *Acetobacter hoshigaki.*
- aaaa. Form acetic acid in alcohol.
  8. *Acetobacter ascendens.*
  9. *Acetobacter plicatum.*

AA. Motile
- a. Form acetic acid in dextrose, ethyl and propyl alcohol and in glycol.
  10. *Acetobacter acetigenum.*
- aa. Form acetic acid in dextrose, ethyl and propyl alcohol, glycol, arabinose, levulose, maltose, lactose, raffinose, dextrin, glycerol and mannitol.
  11. *Acetobacter oxydans.*
  12. *Acetobacter industrium.*

1. **Acetobacter pasteurianum** (Hansen) Beijerinck. (*Bacterium pasteurianum* Hansen, Compt. Rend. Carlsberg Lab., Copenhagen, 1879; Beijerinck, Arch. néerl. d. sci. exact. et nat., sér. 2, *6*, 1901, 212.)

Rods: 0.4 to 0.8 by 1.0 micron, occurring singly and in chains, at times showing thick, club-shaped forms. Motility variable.

Wort gelatin colonies: Small, circular, entire, gray, slimy.

Forms a dry, wrinkled, folded pellicle on fluid media.

Aerobic.

Optimum temperature 30°C. Growth occurs between 5° and 42°C.

Habitat: Vinegar; beer and beer wort.

2. **Acetobacter aceti** (Thomsen) Holland. (*Mycoderma aceti* Thomsen, Ann. der Chemie und Pharmazie, 1852, 89; Holland, Jour. Bact., *5*, 1920, 215.)

Rods: 0.4 to 0.8 by 1.0 to 2.0 microns, occurring singly and in long chains, frequently showing large club-shaped forms. Stain yellow with iodine solution. Non-motile.

Forms large, shiny colonies on beer gelatin containing 10 per cent sucrose.

Forms slimy pellicle on fluid media.

Aerobic.

Optimum temperature 30°C.

Habitat: Vinegar.

3. **Acetobacter kuetzingianum** (Hansen) Bergey et al. (*Bacterium kuetzingianum* Hansen, Compt. Rend. Carlsberg Lab., Copenhagen, *3*, 1894, 215; Manual, 1st ed., 1923, 35.)

Short, thick rods, occurring singly. Non-motile.

In beer gelatin the colonies are slimy.

Wort gelatin colonies: Small, entire, with vermiform surface.

Forms a rather thick, folded pellicle on fluid media.

Aerobic.

Optimum temperature 30°C.

Habitat: Beer.

4. **Acetobacter lindneri** (Zeidler) Bergey et al. (*Bacterium lindneri* Zeidler, Cent. f. Bakt., II Abt., *2*, 1896, 729; Manual, 1st ed., 1923, 36.)

Rods, occurring singly and in chains, showing large sausage-shaped involution forms. Non-motile.

Wort gelatin colonies: Small, circular, slightly granular, yellowish-brown, entire.

Dirty, yellowish-brown pellicle on fluid media.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Beer wort.

5. **Acetobacter acetosum** (Henneberg) Bergey et al. (*Bacterium acetosum* Henneberg, Cent. f. Bakt., II Abt., *4*, 1898, 14; Manual, 1st ed., 1923, 36.)

Rods: 0.4 to 0.8 by 1.0 micron, occurring singly and in chains. Non-motile.

Optimum temperature 30° to 36°C.

Habitat: Beer.

6. **Acetobacter xylinum** (Brown) Bergey et al. (*Bacterium xylinum* Brown, Jour. Chem. Soc., London, *49*, 1886, 432; Manual, 1st ed., 1923, 36.)

Rods, occurring singly and in chains. Non-motile.

The cells have a slimy envelope which gives the cellulose reaction.

Forms a film on beer which becomes cartilagenous and falls to the bottom.

Aerobic.

Optimum temperature 30°C.

Habitat: Vinegar.

7. **Acetobacter hoshigaki** (Takahashi and Asai) Bergey et al. (*Bacterium hoshigaki* var. *rosea* Takahashi and Asai, Cent. f. Bakt., II Abt., *82*, 1930, 390.)

Rods: 0.7 to 0.9 by 1.5 to 1.8 microns, generally occurring singly, at most in pairs. Non-motile.

Koji extract agar colonies: Small, granular, circular, glistening, umbonate, becoming brownish.

Wort agar colonies: Circular, milky-white, becoming brownish in center and yellowish at periphery.

Dextrose saké agar: Circular, milky-white, granular, umbonate, entire.

'Hoshigaki' extract agar: Circular, milky-white, granular, becoming yellowish-brown in the center and grayish-white at the periphery.

Koji extract agar streak: Grayish-white, glistening with ciliate margin, becoming purple brown to brown.

Koji extract: Turbid with thin film, ascending on wall of tube.

Bouillon: Turbid with ring formation.

Acid formed in dextrose, levulose, galactose, arabinose, maltose, sucrose, raffinose, dextrin, amylum, glycogen, inulin, glycerol, mannitol, sorbitol, isodulcitol, methyl, ethyl, and propylalcohol.

Forms gluconic acid from dextrose.

Aerobic.

Optimum temperatures 30° to 35°C.

Thermal death-point 50°C. for 5 minutes.

Habitat: Isolated from fermenting mash of dried persimmons (hoshigaki):

8. **Acetobacter ascendens** (Henneberg) Bergey et al. (*Bacterium ascendens* Henneberg, Cent. f. Bakt., II Abt., *4*, 1898, 933; Manual, 1st. ed., 1923, 37.)

Rods, occurring singly, rarely in chains. Non-motile. Do not give the cellulose reaction with iodine solution.

Glucose gelatin colonies: Dry, white, with white area surrounding the colony.

Fluid cultures have a tough pellicle rising on the wall of the flask.
Aerobic.
Optimum temperature 25°C.
Habitat: Isolated from vinegar and from red wine.

9. **Acetobacter plicatum** Fuhrmann. (Cent. f. Bakt., II Abt., *15*, 1906, 377.

Rods: 0.4 to 0.6 by 1.4 to 1.6 microns, in some media staining uniformly and in others showing paler staining forms. At 28 to 30°C. the organism forms swollen and greatly elongated forms. The cellulose reaction is negative. Non-motile.

Wine gelatin: Circular, convex, moist, glistening colonies, light yellowish, viscid.

Agar slant: Pale yellowish, translucent growth.

Dextrose broth: Turbid with thick pellicles.

Potato: Growth limited.

Ferments alcohol to form acetic acid.

Optimum temperature: 25° to 30°C.

Habitat: Wine.

10. **Acetobacter acetigenum** (Henneberg) Bergey et al. (*Bacterium acetigenum* Henneberg, Cent. f. Bakt., II Abt., *4*, 1898, 14; Manual, 1st ed., 1923, 35.)

Rods, occurring singly and in pairs. Motile. Cells give a cellulose reaction with H_2SO_4 and iodine.

Dextrose gelatin colonies: Raised, grayish, slimy.

Fluid cultures show a tough, slimy pellicle.

Aerobic.

Optimum temperature 30°C.

Habitat: Vinegar.

11. **Acetobacter oxydans** (Henneberg) Bergey et al. (*Bacterium oxydans* Henneberg, Cent. f. Bakt., II Abt., *3*, 1897, 223; Manual, 1st. ed., 1923, 36.)

Rods: 0.8 to 1.2 by 2.4 to 2.7 microns, occurring singly and in chains. Motile. The chains show bud-like swellings.

Gelatin colonies: Circular, becoming irregular in shape with peculiar ramifications.

Aerobic.

Optimum temperature 18° to 21°C.

Habitat: Beer.

12. **Acetobacter industrium** (Henneberg) Bergey et al. (*Bacterium industrium* Henneberg, Zeitschr. f. Deutsche Essigindustrie, Berlin, 1898; Cent. f. Bakt., II Abt., *4*, 1898, 933; Manual, 1st ed., 1923, 36.)

Rods: 0.3 to 0.8 by 2.4 to 20 microns, occurring singly and in chains Motile.

Forms pellicle on fluid culture media.

Aerobic.
Optimum temperature 25°C.
Habitat: Beer wort.

Genus VIII. **Thiobacillus** *Beijerinck, 1904.*

Small rod-shaped organisms deriving their energy from the oxidation of sulfides, thiosulfates or elementary sulfur, forming sulfur, persulfates, and sulfates under acid or alkaline conditions and deriving their carbon from carbon dioxide or from bicarbonates and carbonates in solution; some are obligate and some facultative autotrophic. One species is anaerobic.
The type species is *Thiobacillus thioparus* Beijerinck.

1. **Thiobacillus thioparus** Beijerinck. (Cent. f. Bakt., II Abt., *11*, 1904, 593; Nathanson, Mitt. Zool. Station Neapel, *15*, 1903, 655; Düggeli, Die Schwefelbakterien—Neujaresblatt Naturf. Gesell., Zurich, 1919; *Sulfomonas thioparus* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1908, 326.)
Thin, short rods, 0.5 by 3.0 microns. Motile.
Liquid media: Pellicle formation consisting of free sulfur.
Solid media: Colonies small, circular, yellow.
Aerobic.
Optimum reaction: Alkaline.
Autotrophic, deriving its energy from the oxidation of thiosulfate, sulfides and H_2S, also elementary sulfur.
Habitat: Sea water, river water and soil.

2. **Thiobacillus denitrificans** Beijerinck. (Cent. f. Bakt., II Abt., *11*, 1904, 597; *Sulfomonas denitrificans* Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1908, 314.)
Short rods, 0.5 by 3.0 microns long. Motile by means of six to eight peritrichous flagella.
Liquid media: Slight growth.
Solid media: Colonies large, pale, thin, white.
Anaerobic.
Optimum reaction: Alkaline.
Autotrophic, utilizing carbon from CO_2, carbonates and bicarbonates. It oxidizes elementary sulfur and sulfides.
Habitat: Canal and river water; soil.

3. **Thiobacillus trautweinii** Bergey et al. (Thionsäurebakterien, Trautwein, Cent. f. Bakt., II Abt., *53*, 1921, 513; Manual, 2nd ed., 1925, 39.)
Short rods, 0.5 by 1.0 to 2.0 microns. Motile. Gram-negative.
Solid media: Small, white colonies, 1 mm. in diameter.
Liquid media: No sulfur precipitation.
Facultative aerobic; has property of using nitrate as the source of oxygen under anerobic conditions.
Reaction: Limits pH = 6.0 and pH = 10.0, optimum pH = 7.9–8.5.
Facultative autotropic. Oxidizes thiosulfate to dithionate, tetrathio-

nate, and sulfate with no precipitation of sulfur. Can also oxidize sulfides and sulfur.

Develops well on many organic media.

Habitat: Canal water, sewage, and soil.

4. **Thiobacillus thiooxidans** Waksman and Joffe. (Jour. of Bact., *7*, 1922, 239.)

Short rod with rounded ends, occurring singly and in short chains, 0.5 to 0.8 micron in length. Non-motile.

Liquid media: Turbid.

Solid media: Minute, pale, cream-colored colonies.

Aerobic.

Optimum reaction: Acid.

Autotrophic, deriving its energy from the oxidation of elementary sulfur, thiosulfate, and to some extent, sulfides, oxidizing these to sulfuric acid. It utilizes CO_2 as a source of carbon. Carbonates are not used and bicarbonates only in small amounts.

Habitat: Soil around sulfur mines; soils treated with sulfur.

TRIBE II. AZOTOBACTERIEAE COMMITTEE S. A. B., 1920.

Nitrogen Fixing Bacteria.

Genus IX. Azotobacter *Beijerinck, 1901.*

Relatively large rods or even cocci, sometimes almost yeast-like in appearance, dependent primarily for growth energy upon the oxidation of carbohydrates. Motile or non-motile. When motile, with a single or a tuft of polar flagella. Obligate aerobes usually growing in a film upon the surface of the culture medium. Capable of fixing atmospheric nitrogen when grown in solutions containing carbohydrates and deficient in combined nitrogen.

The type species is *Azotobacter chroococcum* Beijerinck.

1. **Azotobacter chroococcum** Beijerinck. (Cent. f. Bakt., II Abt., *7*, 1901, 577 and *9*, 1902, 3.)

Rods: 2.0 to 3.0 by 3.0 to 6.0 microns, occurring in pairs and packets and occasionally in chains. The cells show three or four refractile granules. The organisms are surrounded by a slimy membrane of variable thickness, becoming brownish in older cultures. The coloring matter is soluble in water, alcohol, ether and chloroform. Motile by means of a polar flagellum.

Gelatin colonies: Very small, circular, yellow, granular, later becoming yellowish-brown.

Gelatin stab: Only slight growth in the stab. No liquefaction.

Mannitol agar stab: Gray, becoming brownish.

Broth: No growth.

Litmus milk: Becoming clearer in 10 to 14 days.

Potato: Glossy, barely visible, slimy to wrinkled, chocolate brown.

The organism fixes atmospheric nitrogen and gives off CO_2, utilizing the following substances: Dextrose, levulose, maltose, mannitol, inulin, dextrin, galactose, arabinose, lactose, starch, glycerol, ethyl alcohol, acetate, butyrate, citrate, lactate, malate, propionate and succinate.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

2. **Azotobacter agile** Beijerinck. (Cent. f. Bakt., II Abt., 7, 1901, 561.)

Rods: 4 to 6 microns in length, almost spherical. Actively motile by means of a bundle of 4 to 10 polar flagella.

Grows on media without organic nitrogen compounds.

Mannitol agar colonies: Circular, grayish white, translucent with whitish center.

Washed agar colonies: Show slight bluish-green fluorescence.

Mannitol agar slant: Grayish, translucent, fluorescent.

Plain agar slant: Yellowish-white, smooth, glistening, translucent with opaque center.

Broth: Turbid, with ring formation.

Litmus milk: Becoming clear in 10 to 14 days.

Potato: Yellowish-white, slimy, becoming yellowish-brown.

In the presence of organic acids, a greenish or reddish pigment is formed.

Aerobic.

Optimum temperature 28°C.

Habitat: Isolated from sewage.

3. **Azotobacter vinelandii** Lipman. (New Jersey Agr. Exp. Sta. Rept., *24*, 1903, 217.)

Rods: 2.0 to 3.0 by 3.0 to 6.0 microns, occurring singly, in pairs and short chains. Motile by means of a polar flagellum.

Mannitol agar colonies: Large, circular, white, slightly transparent, with greenish fluorescence.

Dextrose broth: Turbid, with slight flocculent sediment.

Litmus milk: Becoming clearer in 10 to 14 days.

Potato: Flat, yellowish, becoming light brown.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

4. **Azotobacter beijerinckii** Lipman. (New Jersey Agr. Exp. Sta. Rept., *24*, 1903, 217; *25*, 1904, 247.)

Cells 3 to 4 by 5 to 6 microns, occurring singly and in pairs, more rarely in chains. Motile by means of a polar flagellum.

Mannitol agar colonies: Circular, white to sulfur yellow.

Mannitol agar slant: White, becoming sulfur yellow.

Dextrose broth: No turbidity; several flakes floating on the surface.

Litmus milk: Becomes clearer in 10 to 14 days.
Potato: Flat, yellowish, glistening, becoming brownish-yellow.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

5. **Azotobacter woodstownii** Lipman. (New Jersey Agr. Exp. Sta. Rept., *24*, 1903, 217.)
Litmus milk: Becomes clearer in 10 to 14 days.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

6. **Azotobacter vitreum** Löhnis and Westerman. (Cent. f. Bakt., II Abt., *22*, 1908, 234.)
Spherical cells, about 2.0 microns in diameter, occurring singly and in packets. Non-motile.
Mannitol agar colonies: Small, circular, white, slightly translucent, glistening.
Dextrose broth: Slimy sediment.
Litmus milk: Becomes clearer in 10 to 14 days.
Potato: Slight, barely visible growth.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

Genus X. Rhizobium *Frank, 1889.**

Minute rods motile when young. Branching forms abundant and characteristic in plant nodules. Cells usually vacuolated. Obligate aerobes capable of fixing atmospheric nitrogen in symbiosis with plants. Produce nodules upon the roots of leguminous plants.
The type species is *Rhizobium leguminosarum* Frank.

1. **Rhizobium leguminosarum** Frank *emend.* Baldwin and Fred. (Landwirtschäftliche Jahrbücher, *19*, 1890, 523; *Rhizobium polymorphum* Dangeard, *Rhizobium fabae* Dangeard, Le Botaniste, Sér. *16*, 1926, 192–194; Baldwin and Fred, Jour. Bact., *17*, 1929, 146.)

Note: The following binomials have been used for species of this genus. The names given were used by their authors to cover one or more of the species here recognized as belonging to the genus *Rhizobium*. Where a question (?) mark is used it indicates that the species was too poorly described to be recognizable today. *Schinzia cellulicola* Frank, 1877 (all species) Leunis, Synopsis der drei Naturreiche. 2 Theil, Botanik, III Abt.,

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* The section covering genus *Rhizobium* has been submitted to Prof. E. B. Fred, Univ. of Wisconsin, Madison, Wis., for criticism and suggestions.

Kryptogamen, Sec. 914, 1877, 1944; *Schinzia leguminosarum* Frank, 1879 (all species), Bot. Ztg., *37*, 1879, 377; *Phytomyxa leguminosarum* Schroeter (all except *Rhizobium lupini*), Cohn's Kryptogamen-Flora von Schlesien, *3*, I, 1886, 135; *Bacillus radicicola* Beijerinck (all species), Bot. Ztg., *46*, 1888, 725; *Bacillus fabae* Beijerinck (from broad bean) and *Bacillus ornithopi* Beijerinck (from serradella), Bot. Ztg., *48*, 1890, 837; *Cladocytrium tuberculorum* Vuillemin (all species?), Ann. Sci. Agron. Franc. et Étrang., *5*, I, 1888, 121; *Bacterium radicicola* Prazmowski (all species), Landw. Vers. Sta., *37*, 1890, 204; *Rhizobium mutabile* Schneider (several species), *Rhizobium curvum* Schneider (?), *Rhizobium frankii* var. *majus* and var. *minus* Schneider (?), *Rhizobium nodosum* Schneider (?), *Rhizobium dubium* Schneider (?), Bul. Torrey Bot. Club, *19*, 1892, 203; *Rhizobium sphaeroides* Schneider (?), Ber. Deut. Bot. Gesell., *12*, 1894, 11; *Bacillus tuberigenus* Gonnermann and *Micrococcus tuberigenus* Gonnermann, Landw. Jahrb., *23*, 1894, 649 are thought by Fred, Baldwin and McCoy (University of Wisconsin, Studies in Science, No. 5, 1932, 140) not to be true nodule organisms and to be too poorly described to be recognizable today; *Rhyzobium pasteurianum* Mazé (all species), Ann. Inst. Pasteur, *13*, 1899, 145; *Rhizobium radicicola* Hiltner and Störmer (several species) and *Rhizobium beijerinckii* Hiltner and Störmer (from lupine, serradella and soy bean), Arb. Biol. Abt. f. Land- u. Forstwirthschaft a. K. Gesundheitsamte *3*, 1903, 269; *Pseudomonas radicicola* Moore (all species), U. S. Dept. Agr. Bur. Plant Ind., Bul. 71, 1905; *Rhizomonas beijerinckii* Orla-Jensen and *Rhizomonas radicicola* Orla-Jensen (see Hiltner and Störmer) Cent. f. Bakt., II Abt., *22*, 1909, 328; *Bacterium radicicola* Löhnis and Hansen (all species), Jour. Agr. Research, *20*, 1921, 551; *Rhizobium loti* Dangeard (from lotus), *Rhizobium simplex* Dangeard (from sainfoin), *Rhizobium torulosum* (from Scotch broom), Le Botaniste, Sér. *16*, 1926, 195.

Rods: 0.5 to 0.9 by 1.2 to 3.0 microns. Motile with peritrichous flagella. Bacteroids commonly irregular with X, Y, star- and club-shaped forms. Vacuolate forms predominate.

Growth on mannitol agar is rapid, with tendency to spread. Streak is raised, glistening, semi-translucent, white, slimy and occasionally viscous. Considerable gum is formed.

Slight acid production in dextrose, galactose, mannose, lactose and maltose media.

Aerobic.

Optimum temperature 25°C.

Habitat: In root nodules on *Lathyrus*, *Pisum*, *Vicia* and *Lens*.

2. **Rhizobium trifolii** Dangeard. (Le Botaniste, Sér. *16*, 1926, 191.)

Rods: Motile with peritrichous flagella. Bacteroids from nodules are pear-shaped, swollen and vacuolated. Rarely x and y shapes.

Growth on mannitol agar is rapid. The colonies are white becoming turbid with age. Frequently mucilaginous. Streak cultures transparent at first. Growth mucilaginous later flowing down the agar slant and

accumulating as a slimy mass at the bottom. Produces large amounts of gum.

Slight acid production in dextrose, galactose, mannose, lactose and maltose media.

Aerobic.

Optimum temperature 25°C.

Habitat: Causes the formation of root nodules of species of *Trifolium.*

3. **Rhizobium phaseoli** Dangeard. (Le Botaniste, Sér. *16*, 1926, 197.)

Rods: Motile with peritrichous flagella. Bacteroids are usually rod-shaped, often vacuolated with few branched forms. Usually smaller than in *Rhizobium leguminosarum* and *R. trifolii.*

Growth on mannitol agar is rapid with tendency to spread. Streak inoculation is raised, glistening, semi-translucent, white, slimy. Occasionally mucilaginous but this character is not so marked as in *Rhizobium trifolii.*

Very slight acid formation in dextrose, galactose, mannose, sucrose and lactose media.

Aerobic.

Optimum temperature 25°C.

Habitat: Causes nodule formation in the roots of *Phaseolus vulgaris, Ph. angustifolia* and *Ph. multiflorus.*

4. **Rhizobium meliloti** Dangeard. (Le Botaniste, Sér. *16*, 1926, 194.)

Rods: Motile with peritrichous flagella. Bacteroids club-shaped and branched.

Growth on mannitol agar is fairly rapid. The streak is raised, glistening, opaque, pearly white, butyrous. Considerable gum is formed.

Acid formed in dextrose, galactose, mannose and sucrose media.

Aerobic.

Optimum temperature 25°C.

Habitat: Forms nodules on the roots of *Melilotus, Medicago,* and *Trigonella.*

5. **Rhizobium japonicum** (Kirchner) Buchanan. (*Rhizobacterium japonicum* Kirchner, Cohn's Beitrage zur Biol. d. Pflanzen, *7*, 1895, 213; *Pseudomonas japonica* Löhnis and Hansen, *Bacterium japonicum* Löhnis and Hansen, Jour. Agr. Res., *20*, 1921, 551; *Rhizobium sojae* Dangeard, Le Botaniste, Sér. *16*, 1926, 270; Buchanan, Proc. Iowa Acad. Sci., *33*, 1926, 81.

Rods: Motile with monotrichous flagella. Bacteroids of nodules are long and slender with only occasional branched and swollen forms.

Growth on mannitol agar is slow and scant. The streak is slightly raised, glistening, opaque, white, butyrous, with little gum formation.

Pentose sugars give better growth than the hexoses.

Little if any acid formed from carbohydrates. Acid slowly formed from xylose and arabinose.

Aerobic.

Optimum temperature 25°C.
Habitat: Forms nodules on the roots of *Soja max* (soy bean).

6. **Rhizobium lupini** (Schroeter) Eckhardt, Baldwin and Fred. (*Phytomyxa lupini* Schroeter, Cohn's Kryptogamen-Flora von Schlesien, *3*, I, 1886, 135; *Rhizobium minimum* Dangeard, Le Botaniste, Sér. *16*, 1926, 198; Eckhardt, Baldwin and Fred, Jour. Bact., 21, 1931, 273.)

Rods: Motile with flagella 1–4, usually 2 or 3. Bacterioids are vacuolate rods, seldom if ever branched.

Growth on yeast water, mannitol agar is scant to moderate with alkaline reaction.

Beef-peptone gelatin: Little growth with extremely slow liquefaction.

On galactose an alkaline reaction serves to differentiate *Rhizobium lupini* from all fast-growing rhizobia (*R. phaseoli*, *R. meliloti*, *R. trifolii*, and *R. leguminosarum*), an initial alkaline reaction followed more quickly by an acid reaction on rhamnose and xylose separates *R. lupini* from slow-growing *R. japonicum* and the *Rhizobium* from cow pea.

In general *R. lupini* produces slight to moderate acidity on pentose sugars and no change or alkaline reaction on hexoses, disaccharides, and trisaccharides.

Litmus milk: No serum zone, no reduction, and a slight alkaline reaction.

Meager growth on potato and parsnip slants, and carrot agar.

Aerobic.

Optimum temperature 25°C.

Habitat: Forms nodules on the roots of *Lupinus*.

FAMILY II. COCCACEAE ZOPF, 1884.

Cells in their free conditions spherical; during division somewhat elliptical. Division in one, two or three planes. If the cells remain in contact after division, they are frequently flattened in the plane of division, and occur singly, in pairs, tetrads, packets, chains or irregular masses. Motility rare. Endospores probably absent. Metabolism complex, usually involving the utilization of amino acids or carbohydrates. Pigment often produced.

Key to the tribes of the family Coccaceae.

1. **Cell division in one plane only, occurring in pairs and short or long chains. Parasites (except certain lactic acid streptococci and *Leuconostoc*); certain species growing best in media containing serum. Gram-positive.**

   Tribe I. *Streptococceae*, p. 48.

2. **Cell division in one or in two planes at right angles to each other. (Generally occur in pairs or occasionally as tetrads.)**

a. Occur as single organisms, in pairs or as tetrads. Growth rarely voluminous even on special media Gram-negative.
Tribe II. *Neisserieae*, p. 68.
aa. Occur as single organisms, in pairs or frequently in irregular masses. Generally Gram-positive.
Tribe III. *Micrococceae*, p. 72.

TRIBE I. STREPTOCOCCEAE TREVISAN, 1889.

Parasites (thriving only or best on or in the animal body) except genus *Leuconostoc* and part of genus *Streptococcus*. Grow well under anaerobic conditions. Many forms grow with difficulty on serum-free media, none very abundantly. Planes of fission usually parallel, producing pairs of short or long chains, never packets. Pigment, if any, white or orange.

Key to genera of tribe Streptococceae

1. Parasites, growing poorly, or not at all, on artificial media. Cells usually in pairs. Genus I. *Diplococcus*, p. 48.
2. Chiefly parasites. Normally forming short or long chains, sometimes pairs, but never packets. Genus II. *Streptococcus*, p. 50.
3. Saprophytes, usually growing in cane sugar solutions, and fruit juices. Cells in pairs or chains. Genus III. *Leuconostoc*, p. 65.

Genus I. Diplococcus *Weichselbaum, 1886.*

Parasites, growing poorly or not at all on artificial media. Cells usually in pairs, somewhat elongated, encapsulated, sometimes in chains. Gram-positive. Fermentative powers high, most strains forming acid in dextrose, lactose, sucrose and inulin.

The type species is *Diplococcus pneumoniae*, Weichselbaum

1. **Diplococcus pneumoniae** Weichselbaum. (Wiener Med. Jahrbuch, *82*, 1886, 483.)

Microbe septicémique du salive Pasteur, Chamberland and Roux, Compt. rend. Acad. d. Sci., *92*, 1881, 159; Micrococcus of rabbit septicemia Sternberg, National Board of Health Bull. Washington, *2*, 1881, 781; Coccus lancéolé Talamon, Communication à la Société anatom. de Paris, *58*, 1883, 475; *Micrococcus pyogenes tenuis* Rosenbach, Mikroorganismen bei den Wundinfektionskrankheiten des Menschen, 1884, 30 (See Neumann, Cent. f. Bakt. *7*, 1890, 177); *Micrococcus pasteuri* Sternberg, Trans. Pathol. Soc. of Philadelphia, *12*, 1885, 162 (not *Micrococcus pasteuri* Trevisan, I Generi e le Specie delle Batteriacee, Milano, 1889, 34); Pneumoniemikrococcus or Pneumococcus Fränkel, Zeitschr. f. klin. Medizin, *10*, 1886, 402; *Bacillus septicus sputigenus* Flügge, Die Mikroorganismen, 1886, 262; *Bacillus salivarius septicus* Biondi, Zeitschr. f. Hyg., *2*, 1887, 195; *Diplococcus lanceolatus* sive *capsulatus* Foà and Bordoni-Uffreduzzi, Archivio per le Sci. Med., *11*, 1887, 387; *Streptococcus lanceolatus pasteuri* Gamaléia,

Ann. de l'Inst. Pasteur, *2*, 1888, 442; *Streptococcus lanceolatus* Gamaléia, Ann. de l'Inst. Pasteur, *2*, 1888, 443; *Klebsiella salivaris* Trevisan, I Generi e le Specie della Batteriacee, Milano, 1889, 26; *Micrococcus pneumoniae crouposae* Sternberg, Cent. f. Bakt., *12*, 1892, 53; *Diplococcus lanceolatus capsulatus* Kruse and Pansini, Zeitschr. f. Hyg., *11*, 1892, 335; *Diplococcus lanceolatus* incorrectly ascribed to Fränkel by Binaghi, Cent. f. Bakt., I Abt., *22*, 1897, 278; *Bacterium pneumoniae* Migula, System der Bakterien, 1900, 347; *Streptococcus pneumoniae* Chester, Manual, 1901, 63; *Micrococcus lanceolatus* Longcope, Jour. Med. Res., *7*, (N. S. *2*), 1902, 220; *Pneumococcus lanceolatus* Schmidlechner, Zeitsch. f. Geburtshülfe u. Gynäkologie, *56*, 1905, 291; *Pneumococcus pneumoniae* Fried, Jour. Exp. Med., *57*, 1933, 111).

The organism occurs as oval or spherical forms in pairs, or less frequently in short chains, 0.5 to 1.25 micron. The distal ends of each pair of organisms are pointed or lancet-shaped. Encapsulated. Gram-positive.

Gelatin stab: Filiform or beaded growth.

Agar colonies: Small, transparent, grayish, with entire margin. On blood agar the colonies have a bluish to greenish tint but ordinarily do not produce hemolysis.

Broth: Slight turbidity is produced with slight sediment.

Litmus milk: Acid and coagulation.

Potato: No visible growth.

Bile, in proportion of 1:10, added to broth cultures, will dissolve the organisms.

Inulin is fermented.

Aerobic, facultative.

Optimum temperature 37°C.

Common name: Pneumococcus.

Habitat: The commonest cause of lobar pneumonia. Occurs in inflammations of the mucous membrane of the respiratory tract and elsewhere in the body, as meningitis, mastoiditis, etc.

Thirty-two types of *Diplococcus pneumoniae* are recognized on the basis of agglutination with immune serum. Type III is frequently regarded as identical with *Diplococcus mucosus* v. Lingelsheim described below. The former group IV represents a heterogeneous group of organisms that are not agglutinated by either type I, II or III serum. Cooper, Edwards and Rosenstein (Jour. Exp. Med., *49*, 1929, 461; *55*, 1932, 531) recognize ten types previously included under group IV and number these as types IV to XIII inclusive. Cooper, Rosenstein, Walter and Peizer (Jour. Exp. Med., *55*, 1932, 531) recognize additional types, nos. XIV to XXXII.

2. **Diplococcus mucosus** (Howard and Perkins) v. Lingelsheim. (*Streptococcus mucosus* Howard and Perkins, Jour. Med. Res., *6* (N. S. *1*), 1901, 174; *Diplococcus capsulatus* incorrectly attributed to Fränkel by Binaghi, Cent. f. Bakt., I Abt., *22*, 1897, 273; *Streptococcus mucosus* Schottmüller, Münch. med. Wchnschr., *50*, 1903, 909; *Streptococcus lanceolatus*

var. *mucosus* Park and Williams, *Diplococcus lanceolatus* var. *mucosus* Park and Williams, *Pneumococcus mucosus* Park and Williams, Jour. Exp. Med., *7*, 1905, 411; *Streptococcus mucosus capsulatus* Buerger, Cent. f. Bakt., I Abt., *41*, 1906, 314; v. Lingelsheim, Zeitschr. f. Hyg., *59*, 1908, 457; *Pneumococcus mucosus* Dochez and Avery, Jour. Exp. Med., *21*, 1915, 114.)

Note: Buerger (Cent. f. Bakt., I Abt., *41*, 1906, 314) lists the following capsulated streptococci which are closely related to and sometimes regarded as identical with *Diplococcus mucosus: Streptococcus involutus* Kurth, Arb. a. d. k. Gesundheitsamte, *8*, 1893, 449; *Streptococcus aggregatus* Seitz, Cent. f. Bakt., I Abt., *20*, 1896, 854; *Streptococcus capsulatus* Binaghi, Cent. f. Bakt., I Abt., *22*, 1897, 273; *Leuconostoc hominis* Hlava, Cent. f. Bakt., I Abt., Orig., *32*, 1902, 263. To this list should be added *Diplococcus involutus* Winslow and Winslow, The Systematic Relationships of the Coccaceae, New York, 1908, 131.

Spherical to oval organisms, 0.6 to 0.8 microns in diameter, occurring singly and in pairs, occasionally in chains. A capsule has been demonstrated.

Ascitic agar colonies: Small, clear, smooth, somewhat convex, mucinous, becoming gray or grayish-white, translucent.

Dextrose agar: Growth frequently becomes confluent, grayish.

Aerobic, facultative.

Optimum temperature 37°C., but growth takes place at room temperature.

The description of biological characters is incomplete but the morphological characters suggest that this is type III of the pneumococcus.

Habitat: Originally isolated from the nasopharynx in epidemic meningitis where it is sometimes associated with the meningococcus. Some strains are reported to be pathogenic for animals on inoculation.

3. **Diplococcus pluton** (White) Bergey et al. (*Bacillus pluton* White. U. S. Dept. of Agr., Bur. of Entomol., Circ. 157, 1912; Manual, 2nd ed., 1925, 45.)

In early infection the organism occurs as short rods in pairs or chains, later it takes on the appearance of a lancet shaped coccus, usually less than 1.0 micron in length. Spores are not formed. Non-motile. Gram-positive. Does not grow on artificial media.

Thermal death-point 79°C. for ten minutes.

Resists exposure to direct sunlight for about 30 days when in dry state, for 5 days when suspended in water, for 3 hours when suspended in honey.

Habitat: The cause of European "Foulbrood" of bees.

Genus II. **Streptococcus** *Rosenbach, 1884.*

Cells in pairs or short or long chains, never in packets. Gram-positive. Capsules rarely formed. Do not form zoogleal masses. Grow as effused, translucent, often small isolated colonies on agar streak. In stab cultures

little surface growth is developed. Many carbohydrates are fermented with formation of dextro lactic acid, but inulin is rarely attacked. Generally fail to liquefy gelatin. Do not reduce nitrates. Action on blood variable.

The type species is *Streptococcus pyogenes* Rosenbach.

Key to the species of genus Streptococcus

1. Parasites on or in the animal body.
    A. Hemolytic group. Beta type.
        a. Acid in lactose.
        b. No acid in mannitol.
        c. Acid in salicin.
        d. Found in acute pathological conditions in man.
            1. *Streptococcus pyogenes.*
        dd. Found in specific human diseases.
        e. Scarlet fever.
            2. *Streptococcus scarlatinae.*
        ee. Puerperal septicemia.
            3. *Streptococcus puerperalis.*
        eee. Erysipelas.
            4. *Streptococcus erysipelatis.*
        eeee. Epidemic sore throat.
            5. *Streptococcus epidemicus.*
        ddd. Found in a disease of rabbits.
            6. *Streptococcus cuniculi.*
        cc. No action on salicin.
        d. Found in sore throat.
            7. *Streptococcus anginosus.*
        dd. Found in natural infection in cats.
            8. *Streptococcus felinus.*
        bb. Acid in mannitol.
        c. Acid in salicin.
        d. Found in inflammatory conditions in man.
            9. *Streptococcus stenos.*
        dd. Found in pyogenic inflammations.
            10. *Streptococcus mixtus.*
        ddd. Found in nose and throat.
            11. *Streptococcus infrequens.*
        aa. No action on lactose.
        b. No action on mannitol.
        c. Acid in salicin.
            12. *Streptococcus equi.*
        cc. No action on salicin.
            13. *Streptococcus subacidus.*

B. Blood agar colonies greenish. Viridans group. Alpha type.
a. Acid in lactose.
b. No action on mannitol.
c. Acid in salicin.
14. *Streptococcus mitior.*
cc. No action on salicin.
d. No action on raffinose.
15. *Streptococcus morbilli.*
dd. Acid in raffinose.
e. No acid in arabinose.
16. *Streptococcus salivarius.*
ee. Acid in arabinose.
17. *Streptococcus bovis.*
bb. Acid in mannitol.
c. Acid in salicin.
d. From bovine mastitis.
18. *Streptococcus mastitidis.*
dd. From intestinal contents and dairy products.
19. *Streptococcus faecalis.*
aa. No action on lactose.
b. No action on mannitol.
c. Acid in salicin.
20. *Streptococcus equinus.*
cc. No action on salicin.
21. *Streptococcus ignavus.*

C. Blood agar colonies without hemolysis or green coloration. Gamma type.
a. Acid in lactose.
b. No action on mannitol.
c. Acid in salicin.
22. *Streptococcus anhaemolyticus.*
bb. Acid in mannitol.
c. Acid in salicin.
23. *Streptococcus saprophyticus.*
aa. Action on lactose variable.
b. No action on mannitol.
c. Acid in salicin.
24. *Streptococcus cardioarthritidis.*

2. Saprophytes occurring principally in dairy products.
a. Does not liquefy gelatin.
b. Acid in maltose.
c. No action on inulin or glycerol.
25. *Streptococcus lactis.*
cc. Acid in inulin.
26. *Streptococcus inulinaceus.*

cc. Acid in glycerol.

27. *Streptococcus glycerinaceus.*

bb. No action on maltose or pentoses.

c. Grows at 35° to 38°C.

28. *Streptococcus cremoris.*

cc. Grows at 45° to 50°C.

29. *Streptococcus thermophilus.*

aa. Liquefies gelatin.

30. *Streptococcus liquefaciens.*

3. Occurring in foul brood of bees.

31. *Streptococcus apis.*

Note: Attempts to classify streptococci on the basis of their powers to ferment different carbohydrates give no concordant results with serological tests in the form of agglutination reactions and absorption of agglutinins For these reasons, the species of streptococci of human and animal origin are here grouped on the basis of action in blood agar; serological reactions; and only secondarily on the basis of carbohydrate fermentation.

1. **Streptococcus pyogenes** Rosenbach. (Mikroorganismen bei Wundinfectionskrankheiten des Menschen, 1884, 22.)

Note: The following are the most important names that have been used for species of pyogenic (beta hemolytic) streptococci. For their relationships to *Streptococcus pyogenes* see "The Systematic Relationships of the Coccaceae," Winslow and Winslow, New York, 1908, 139; Thomson and Thomson, Annals Pickett-Thomson Res. Lab. *3*, 1927, 131; McLeod, System of Bact., Med. Res. Council London, *2*, 1929, 30.

Streptococcus longus v. Lingelsheim, Zeitschr. f. Hyg., *10*, 1891, 331 and *12*, 1892, 308; *Streptococcus conglomeratus* Kurth from scarlet fever, Arb. d. k. Gesundheitsamte, *7*, 1891, 389; *Streptococcus longus pathogenes* seu *erysipelatos* Schottmüller, Münch med. Wchnschr., *50*, 1903, 909; *Streptococcus longus hemolyticus* Sachs, Zeitschr. f. Hyg., *63*, 1909, 466; *Streptococcus longissimus* Thalmann, Cent. f. Bakt., I Abt., *56*, 1910, 248; *Streptococcus hemolyticus* Rolly, Cent. f. Bakt., I Abt., *61*, 1911, 87; *Streptococcus hemolysans* Blake, Jour. Med. Res., *36* (N. S. *31*), 1917, 116.

Spheres: 0.6 to 1.0 micron in diameter, in blood and pus, very variable in cultures. Gram-positive. Occur in chains.

Gelatin stab: Small opaque colonies in stab. No liquefaction.

Produces typical hemolysis on blood agar plates, both deep and surface colonies being surrounded by a zone of hemolysis up to two or three millimeters in width.

Broth: Slight, flocculent sediment.

Litmus milk: Markedly acid. No coagulation.

Potato: No visible growth.

Acid formed in media containing dextrose, lactose, sucrose and salicin. Does not ferment inulin, glycerol, mannitol or dulcitol.

Aerobic, facultative.

Pathogenic.

Habitat: This is the common streptococcus found in acute pathological conditions in man, as wounds, cellulitis, middle-ear disease, mastoid and sinus disease, infection of the serous cavities, brain and spinal cord, bones, joints, metritis and general septicemia.

2. **Streptococcus scarlatinae** Klein. (*Micrococcus scarlatinae* Klein, Report of the Medical officer of the Local Government Board for 1885–1886, No. 8, 1887, 85; also used *Streptococcus scarlatinae* in the same report.)

Morphologic and cultural characters similar to those of *Streptococcus pyogenes*.

Gelatin stab: Small opaque white colonies. No liquefaction.

Litmus milk: Acid; generally not coagulated.

Acid formed in dextrose, galactose, maltose, lactose, sucrose, and salicin. No acid formed in inulin or mannitol.

Habitat: Found commonly in the throat of scarlet fever patients.

3. **Streptococcus puerperalis** Arloing. (Septicémie puerperale, Paris, 1892; Jordan, J. F., Brit. Med. Jour., July, 1912.)

Spheres: 0.6 to 0.8 micron in diameter, occurring in long chains. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Rather larger than those of *Streptococcus pyogenes;* opaque.

Blood agar colonies: Wide zone of hemolysis.

Agar slant: Gray, filiform streak.

Broth: Turbid.

Litmus milk: Acid; coagulated.

Acid in dextrose, lactose, sucrose and salicin. No action on raffinose, inulin or mannitol.

Distinguished from the other pyogenic streptococci by its specific serologic reactions.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: In puerperal septicemia.

4. **Streptococcus erysipelatis** Rosenbach. (Fehleisen, Ueber Erysipel, Deut. Zeit. f. Chir., *16*, 1882, 391; Erysipelkokken, Fehleisen, Die Aetiologie des Erysipels, Berlin, 1883; *Streptococcus erysipelatos* Rosenbach. Incorrect spelling is probably due to orthographic error so that the binomial is credited to Rosenbach, Microorganismen bei Wundinfectionskrankheiten des Menschen, 1884, *22*, not to Zopf, Die Spaltpilze, 1885, 51; *Streptococcus erysipelatosus* Klebs, Die Allg. Path., Jena, 1887, 318; Birkhaug, Studies on the biology of *Streptococcus erysipelatis*, Bul. Johns Hopkins Hosp., *36*, 1925, 248.)

Spheres: 0.6 to 0.8 micron, occurring in long chains. Gram-positive.
Gelatin stab: No liquefaction.
Blood agar colonies: Wide zone of hemolysis.
Agar slant: Filiform streak.
Broth: Turbid.
Litmus milk: Acid. Some strains show coagulation.
Acid in dextrose, lactose, sucrose and salicin. No action on inulin or mannitol.
Distinguished from the other pyogenic streptococci by its specific serologic reactions.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: The cause of erysipelas.

5. **Streptococcus epidemicus** Davis. (Jour. Am. Med. Assoc., *58*, 1912, 1852; Jour. Infect. Dis., *15*, 1914, 378; ibid., *19*, 1916, 236.)
Spheres: 0.6 to 0.8 micron in diameter, occurring in long chains. Encapsulated. Gram-positive.
Gelatin stab: No liquefaction.
Blood agar colonies: Wide zone of hemolysis.
Agar slant: Filiform streak.
Broth: Turbid.
Litmus milk: Acid; coagulated.
Acid in dextrose, lactose, sucrose and salicin. No action on raffinose, inulin or mannitol.
Does not hydrolyze sodium hippurate.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: The cause of epidemic sore throat. Rarely found in udders of cows.

Note: In her recent book (Streptococci in Health and Disease, Williams & Wilkins Co., Baltimore, Md., 1930, 176) Anna W. Williams presents laboratory evidence to support the view that the hemolytic streptococci occurring in scarlet fever, erysipelas, epidemic sore throat, and other infections, should not be classed as independent species but as varieties of one species which she designates *Streptococcus hemolyticus* Rolly.

6. **Streptococcus cuniculi** Bergey et al. (Manual, 1st ed., 1923, 50.)
Morphologically like *Streptococcus pyogenes*. Serologically different.
Litmus milk: Acid; coagulated.
Acid formed in lactose and salicin.
Aerobic, facultative.
Pathogenic.
Habitat: Isolated by Roos. The cause of natural infection in rabbits.

7. **Streptococcus anginosus** Andrewes and Horder. (The Lancet, *2*, 1906, 708.)

Spheres: 0.6 to 0.8 micron in diameter, occurring in long chains. Gram-positive.

Gelatin stab: No liquefaction.

Blood agar colonies: Show zone of hemolysis.

Agar slant: Filiform streak.

Broth: Turbid, with flocculent sediment.

Litmus milk: Acid; coagulated; litmus reduced.

Acid in dextrose, lactose, sucrose, sometimes in raffinose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Frequently found in sore throat.

8. **Streptococcus felinus** Bergey et al. (*Streptococcus hemolyticus* Bayne-Jones, Jour. Infect. Dis., *31*, 1922, 477; Manual, 1st ed., 1923, 50.)

Morphologically like *Streptococcus pyogenes*. Serologically different.

Litmus milk: Acid.

Aerobic, facultative.

Pathogenic.

Habitat: The cause of natural infection in cats.

9. **Streptococcus stenos** Bergey et al. (Manual, 1st ed., 1923, 50.)

This organism does not absorb agglutinins from *Streptococcus pyogenes* serum. Culturally different from *Streptococcus pyogenes* in the production of a narrow zone of hemolysis around the colonies in blood agar.

Litmus milk: Acid; coagulated.

Acid formed in dextrose, lactose, sucrose, salicin and mannitol. No action on inulin.

Aerobic, facultative.

Pathogenic.

Habitat: Occurs in a variety of inflammatory conditions in man.

10. **Streptococcus mixtus** Bergey et al. (Manual, 1st ed., 1923, 49.)

Probable synonyms: *Streptococcus infrequens* Holman, *Streptococcus hemolyticus II* Holman. (Jour. Med. Res., *34* (N. S. *29*), 1916, 388.)

Morphologic characters are similar to those of *Streptococcus pyogenes*, but culturally, these organisms are different in the carbohydrates fermented, and do not all agree in this particular, though they agree serologically.

Habitat: Found in a variety of pyogenic inflammations.

11. **Streptococcus infrequens** Holman. (Jour. of Med. Res., *34* (N. S. *29*) 1916, 388.)

Spheres: 0.6 to 0.8 micron in diameter, occurring in chains. Gram-positive.

Gelatin stab: No liquefaction.

Blood agar colonies: Show zone of hemolysis.

Agar slant: Filiform streak.

Broth: Turbid.

Litmus milk: Acid; coagulated.

Acid in dextrose, lactose, salicin and mannitol. No action on sucrose, raffinose or inulin.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Nose and throat.

12. **Streptococcus equi** Schütz. (Arch. f. wissenschaftl. u. prakt. Tierheilkunde, *14*, 1888, 172.)

Note: The relationship of *Streptococcus equi* Schütz to *Streptococcus equi* of other authors is discussed by Williams (Streptococci in Health and Disease, Baltimore, 1932, 69).

Spheres: 0.7 to 0.9 micron. Occur singly, in pairs and chains. Gram-positive. A capsule is present in cultures on serum media.

Serologically it differs from *Streptococcus pyogenes*.

Broth: Clear, flocculent sediment.

Litmus milk: Acid; slow coagulation.

Acid in media containing raffinose, inulin and salicin. No action on lactose nor mannitol.

Aerobic, facultative.

Pathogenic.

Habitat: The cause of 'strangles' in horses. Found occasionally in inflammatory conditions in man.

13. **Streptococcus subacidus** Holman. (Jour. of Med. Res., *34* (N. S. *29*) 1916, 388.)

Spheres: 0.6 to 0.8 micron in diameter, occurring in chains. Gram-positive.

Gelatin stab: No liquefaction.

Blood agar colonies: Show zone of hemolysis.

Agar slant: Filiform streak.

Broth: Turbid.

Litmus milk: Unchanged.

Acid in dextrose and sucrose. No action on lactose, salicin, inulin or mannitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Local and general infections in man.

14. **Streptococcus mitior** Schottmüller. (Münch. Med. Wchnschr., *50*, 1903, 849. Many workers use the alternative name, *Streptococcus viridans* proposed by Schottmüller in the same article.)

Note: The following are the most important names that have been used for species of streptococci that are closely related to or identical with *Streptococcus mitior*: *Streptococcus brevis* v. Lingelsheim (Zeitschr. f. Hyg., *10*, 1891, 331 and *12*, 1892, 308); *Streptococcus brevis non hemolyticus* Sachs (Zeitschr. f. Hyg., *63*, 1909, 466). For the relationship of *Streptococcus*

mitior to *Streptococcus mitis* Andrewes and Horder (Lancet, *2*, 1906, 712) see Thomson and Thomson (Annals Pickett-Thomson Res. Lab., *3*, 1927, 166).

Litmus milk: Acid; coagulated; reduction of litmus.

Acid formed in media containing dextrose, lactose, salicin and sucrose.

Aerobic, facultative.

Generally not pathogenic for laboratory animals.

Habitat: Nose and throat. Encountered in abcesses of teeth and in endocarditis.

15. **Streptococcus morbilli** Ferry and Fisher. (Jour. Amer. Med. Ass., *86*, 1926, 932.)

Small spheres, occurring singly, in pairs and in short chains of 4 to 10 elements. Gram-positive.

Blood agar colonies: Small, smooth, with wide green zone.

Blood agar slant: Filiform streak.

Broth: Uniform turbidity.

Litmus milk: Marked acidity; coagulated. Litmus reduced.

Acid formed in dextrose, lactose and sucrose. No acid in inulin, salicin and mannitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from blood, nose, throat and conjunctiva of measles patients.

16. **Streptococcus salivarius** Andrewes and Horder. (The Lancet, *2*, 1906, 712.)

Spheres: 0.6 to 0.8 micron in diameter, usually occurring in pairs and short chains. Gram-positive.

Gelatin stab: No liquefaction.

Blood agar colonies: Greenish.

Agar slant: Filiform streak.

Broth: Turbid, with slight sediment.

Litmus milk: Acid; coagulated.

Acid formed in dextrose, lactose, sucrose, raffinose, rarely in salicin, coniferin or inulin.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Commonly found in the saliva, also in the intestinal tract.

17. **Streptococcus bovis** Orla-Jensen. (The Lactic Acid Bacteria, 1919, 137.)

Note: *Streptococcus bovis* as defined by Ayers and Mudge (Jour. Inf. Dis., *31*, 1923, 50) includes two varieties A and B. According to Sherman and Stark (Jour. Bact., *22*, 1931, 279) these include the inulin fermenting strains placed by Orla-Jensen in *Streptococcus inulinaceus*.

Litmus milk: Acid; coagulated in three to five days. Capsules are formed.

Acid in dextrose, levulose, mannose, galactose, maltose, lactose, sucrose, raffinose, salicin, dextrin, starch and arabinose. Does not ferment inulin readily.

Aerobic, facultative.

Not pathogenic.

Optimum temperature 35°C.

Habitat: The most common streptococcus in cow dung. Frequently occurs in milk.

18. **Streptococcus mastitidis** Migula. (Streptocococcus de la mammite Nocard and Mollereau, Ann. de l'Institut Pasteur, *1*, 1887, 109; *Streptococcus mastitis sporadicae* Guillebeau, *Streptococcus mastitis contagiosae* Guillebeau, Landw. Jahrb. d. Schweiz., *4*, 1892, 27, Abst. in Cent. f. Bakt., *12*, 1892, 101; *Streptococcus agalactiae contagiosae* Kitt, Bakterienkunde, 1893, 322; *Streptococcus agalactiae* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 126; Migula, System der Bakterien, 1900, 19.)

Morphologically like *Streptococcus pyogenes*. Serologically it is different.

Gelatin stab: Small, white, opaque colonies growing into a thick line. No liquefaction.

Dextrose broth: Clear with flocculent deposit; long chains formed.

Ferments dextrose, lactose, raffinose, salicin, inulin, amylum and mannitol.

Litmus milk: Acid; coagulated; with yellow surface fluid.

Potato: No visible growth.

Aerobic, facultative.

Pathogenic.

Habitat: The cause of infectious mastitis in cows frequently called "gelbe galt." Orla-Jensen reports finding this organism in mastitis in a woman.

19. **Streptococcus faecalis** Andrewes and Horder. (Lancet, *2*, 1906, 712; *Enterococcus* Thiercelin, Compt. rend. de la Société de Biologie, 1902, no. 27; *Streptococcus faecium* Orla-Jensen, The Lactic Acid Bacteria, 1919, 61.)

Spheres, ovals, of variable size. Gram-positive.

Gelatin stab: No liquefaction.

Broth: Turbid, then clearing. With thick white sediment.

Litmus milk: Acid; coagulated.

Potato: No visible growth.

Acid in media containing dextrose, levulose, galactose, maltose, lactose, sucrose, salicin, mannitol and arabinose. No acid in inulin.

Aerobic, facultative.

Optimum temperature 36° to 37°C.

Ordinarily not pathogenic. Has been encountered in lesions of the internal organs.

Habitat: Intestines of men and cattle, and from milk and cheese.

20. **Streptococcus equinus** Andrewes and Horder. (Lancet, *2*, 1906, 712.)

Litmus milk: Unchanged.

Acid in media containing dextrose, sucrose and salicin. No acid in lactose nor mannitol.

Aerobic, facultative.

Not pathogenic.

Habitat: Intestines of horses and cows.

21. **Streptococcus ignavus** Holman. (Jour. of Med. Res., *34* (N. S. *29*), 1916, 388.)

Litmus milk: Unchanged.

Acid in media containing dextrose, sucrose, raffinose, and inulin. No acid in lactose, mannitol nor salicin.

Aerobic, facultative.

Not pathogenic.

Habitat: Isolated from nose and throat.

Note: The alpha hemolytic type that is characterized by the small amount of acidity developed in test substances is named *Streptococcus acidominimus* by Ayers and Mudge (Jour. Infect. Dis., *31*, 1922, 49).

22. **Streptococcus anhaemolyticus** Zangmeister. (Munch. Med. Wochenschr., *57*, 1910, 1268.)

Litmus milk: Unchanged.

Acid in media containing dextrose, sucrose, raffinose and salicin.

Aerobic, facultative.

Not pathogenic.

Habitat: Found on normal mucous membranes, as mouth, nose, vagina and intestines.

23. **Streptococcus saprophyticus** Mandelbaum. (Zeitschr. f. Hyg., *58*, 1907–08, 37.)

Litmus milk: Acid; coagulation; reduction of litmus.

Acid in media containing dextrose, lactose, sucrose and salicin.

Aerobic, facultative.

Pathogenic.

Habitat: Obtained from vagina; also from nasopharynx in acute catarrhal inflammation.

24. **Streptococcus cardioarthritidis** Small. (Am. Jour. Med. Sci., *173*, 1927, 101.)

Spheres ranging from 0.7 to 1.2 microns in diameter, occurring in chains. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: No liquefaction.

Blood agar colonies: Small, grayish-white, opaque, red-brown. No hemolysis. No methemoglobin formation.

Blood agar slants: Cultures stored in an ice-box for several weeks change to a brown color.

Infusion broth: Diffuse turbidity.

Litmus milk: Acid; coagulated. Some strains leave the medium unchanged.

Potato: No growth.

Indol is not formed.

Nitrates.

Acid in dextrose, raffinose, sucrose, inulin, salicin, while some strains also attack lactose.

Aerobic.

Optimum temperature 37°C.

Habitat: Throat and blood in acute articular rheumatism.

25. **Streptococcus lactis** (Lister) Löhnis. (*Bacterium lactis* Lister, Quart. Jour. Micro. Sci., *13*, 1873, 380, Apr., 1878; Löhnis, Cent. f. Bakt., *22*, 1909, 553.)

Note: The following organisms are generally regarded as identical with *Streptococcus lactis* Löhnis. See Breed in Jordan and Falk, The Newer Knowledge of Bacteriology and Immunology, Chicago, 1928, 383.

Streptococcus acidi lactici Grotenfelt, Fortschr. d. Med., 7, 1889, 121; *Micrococcus acidi paralactici* Nencki and Sieber, Monatschr. f. Chem., *10*, 1889, 532; Bacillus No. 19 Adametz, Landw. Jahrb., *18*, 1889, 227; *Bacillus acidi lactici* Günther and Thierfelder, Arch. f. Hyg., *25*, 1895, 164, and Esten, Storrs Agric. Exper. Sta. Conn., Ann. Rep. for 1896, 1897, 44; (Not Milchsaurebacterium Hueppe, Mitt. d. kais., Gesundheitamte, *2*, 1884, 309; Not *Bacillus acidi lactici* Zopf, Die Spaltpilze, 3d ed., 1885, 60); *Bacterium güntheri* Lehmann and Neumann, Bakteriologische Diagnostik, 1st ed., 1896, 197; *Bacterium lactis acidi* Leichmann, Cent. f. Bakt., II Abt., *2*, 1896, 777; (Not *Bacterium lactis acidi* Marpmann, Erganzungshefte Cent. f. allgem. Gesundheitspflege, *2*, 1886, 117); Der ovaler coccus Freudenreich, Cent. f. Bakt., II Abt., 1895, 168; *Bacillus lacticus* Kruse, Flügge's Die Mikroörganismen, 1896, 356; *Bacterium lacticus* Chester, Delaware Agr. Exper. Sta., 9th Ann. Rep., 1897, 88; *Bacillus acidi paralactici* Kozai, Ztschr. f. Hyg., *31*, 1899, 372; *Bacterium lacticum* Migula, System der Bakterien, *2*, 1900, 405; *Bacterium truncatum* Migula, System der Bakterien, *2*, 1900, 407 (Bacillus No. 19 of Adametz); *Lactococcus lactis* Beijerinck, Arch. Neérl. d. Sci. Exact. et Nat., Sér. II, *7*, 1901, 213; *Streptococcus lacticus* Kruse, Cent. f. Bakt., I Abt., *34*, 1903, 737; *Streptococcus güntheri* Lehmann and Neumann, Bakteriologische Diagnostik, 4th ed., 1904, 242; *Bacillus lactis acidi* Sewerin, Cent. f. Bakt., II Abt., *22*, 1908, 8 (Not *Bacillus lactis acidi* Marpmann, loc. cit., p. 120, nor Leichmann loc. cit., 778); *Bacterium leichmanni* Wolff, Cent. f. Bakt., II Abt., *24*, 1909, 57.

Spheres, with many cells slightly longer than broad; dimensions usually

fall between 0.5 to 1 micron; pairs and short chains with an occasional culture showing long chains. Gram-positive.

Whey gelatin stab: Filiform to beaded growth, medium in amount; no liquefaction.

Agar colonies: Small, round or oval, gray entire edge, only slightly raised.

Agar slant: Tendency to formation of small definite colonies throughout growth area; in some portions growth becomes confluent.

Dextrose broth: Usually first a turbidity and later a sediment.

Litmus milk: Rapid or fairly rapid coagulation with pronounced reduction of the litmus. Young cultures entirely reduced except for narrow red band at top; the red band increases in width as the culture ages. No gas. No evident digestion although whey may be expressed.

Potato: No visible growth.

Indol: Not formed.

Nitrates: Not reduced.

Acid formed in dextrose, levulose, galactose, maltose, lactose and with some cultures in sucrose.

Aerobic, facultative.

Optimum temperature is quite variable with different cultures.

Not pathogenic.

Habitat: Milk. The common cause of souring of milk. Active in the ripening of cheese.

Hammer and Baker (Iowa Agr. Exp. Station, Research Bul. 99, 1926, 286) recognize five varieties of *Streptococcus lactis* which are described below. The relationships of these varieties to the species of lactic acid streptococci recognized by Orla-Jensen are not entirely clear.

A. *Streptococcus lactis* var. *maltigenes* Hammer and Cordes. (Research Bul. Iowa Agr. Exp. Station, No. 68, 1921.)

Cultures varying from typical *Streptococcus lactis* by producing a malt-like (or caramel or burnt) flavor and odor in milk and milk products.

B. *Streptococcus lactis* var. *hollandicus* Buchanan and Hammer. (Research Bul. Iowa Agr. Exp. Sta., No. 22, 1915.)

Cultures varying from typical *Streptococcus lactis* by producing a ropiness in milk.

C. *Streptococcus lactis* var. *anoxyphilus* Hammer and Baker. (Research Bul. Iowa Agr. Exp. Sta., No. 99, 1926.)

Cultures varying from typical *Streptococcus lactis* by a comparatively slow reduction of litmus.

D. *Streptococcus lactis* var. *tardus* Hammer and Baker. (Research Bul. Iowa Agr. Exp. Sta., No. 99, 1926.)

Cultures varying from typical *Streptococcus lactis* by a comparatively slow coagulation of milk.

E. *Streptococcus thermophilus* Orla-Jensen. (The Lactic Acid Bacteria, 1919, 136.)

Cultures varying from typical *Streptococcus lactis* mainly in the resistance to heat and in the growth temperature. For a more complete description see No. 29, *Streptococcus thermophilus* Orla-Jensen.

Note: *Streptococcus distendens* Hammer (Iowa State Coll. Jour. Sci., *2*, 1927, 5.) appears to be a variant strain of *Streptococcus lactis* Löhnis.

Spheres 0.7 to 0.9 micron.

Resembles *Leuconostoc citrovorum* (Hammer) Hucker and Pederson in the amount of volatile acid produced. However, it differs in that the amount of volatile acid produced is not increased by adding lactic or citric acid to milk.

Habitat: Produces a bulging of cans of evaporated milk.

Streptococcus lactis Löhnis *emend.* S. Orla-Jensen. (The Lactic Acid Bacteria, 1919, 130.)

By definition, Orla-Jensen restricts this species to those maltose fermenting lactic acid streptococci that do not produce acid from sucrose, inulin nor glycerol. The species of lactic acid streptococci recognized by Orla-Jensen that do ferment these carbohydrates are listed as No. 26. *Streptococcus inulinaceus* Orla-Jensen and as No. 27. *Streptococcus glycerinaceus* Orla-Jensen.

Orla-Jensen, A. D. and Hansen, P. A. (Cent. f. Bakt., II Abt., *86*, 1932, 6) have named several variants of *Streptococcus lactis* Löhnis *emend.* S. Orla-Jensen which differ only in their ability to ferment certain other carbohydrates.

Streptococcus saccharolactis, ferments sucrose.
Streptococcus raffinolactis, ferments raffinose.
Streptococcus amylolactis, ferments starch.

26. **Streptococcus inulinaceus** Orla-Jensen. (The Lactic Acid Bacteria, 1919, 138.)

Spheres: 0.6 to 0.8 micron, in short chains. Gram-positive.

Litmus milk; Acid; coagulated in two to three days.

Acid formed in dextrose, levulose, galactose, mannose, maltose, lactose, sucrose, raffinose, dextrin, starch, inulin, salicin and mannitol. Does not ferment arabinose.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Sour milk and bovine feces.

27. **Streptococcus glycerinaceus** Orla-Jensen. (The Lactic Acid Bacteria, 1919, 140.)

Characters the same as those for *Streptococcus liquefaciens* Orla-Jensen except that it does not liquefy gelatin.

Habitat: Milk and cheese.

28. **Streptococcus cremoris** Orla-Jensen. (The Lactic Acid Bacteria, Copenhagen, 1919, 132.)

Spheres: 0.6 to 0.7 micron, forming long chains. Gram-positive.

Litmus milk: Acid; coagulated (0.7 per cent acid formed). It breaks up casein to some extent. Milk frequently becomes slimy.

Acid formed in dextrose, levulose, galactose, mannose and lactose. Maltose not attacked.

Aerobic, facultative.

Optimum temperature 20°C. Thermal death point 65 to 70°C.

Habitat: Commercial "starter" in butter and cheese factories.

Orla-Jensen, A. D., and Hansen, P. A. (Cent. f. Bakt., II Abt., *86*, 1932, 6) have named a variant of *Streptococcus cremoris* which differs in its ability to ferment carbohydrates.

Streptococcus mannitocremoris, ferments mannitol.

29. **Streptococcus thermophilus** Orla-Jensen. (Maelkeri-Bakteriologi, 1916, 37; The Lactic Acid Bacteria, 1919, 136.)

Spheres: 0.7 to 0.9 micron, with pointed ends, occurring singly and in short chains. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Small, gray, circular.

Agar slant: Scanty, beaded, gray.

Broth: Fine sediment.

Litmus milk: Acid; coagulated. Litmus partly reduced.

Potato: No visible growth.

Indol not formed.

Nitrates not reduced.

Ammonia not formed.

H_2S not formed.

Acid in dextrose, levulose, lactose and sucrose. Maltose, galactose and mannose are also attacked by some strains.

Acts on malonic, succinic, malic, fumaric and hippuric acid.

Aerobic, facultative.

Many strains will grow at 30°C., but the optimum temperature is 40° to 50°C.

Thermal death-point 72° to 74°C.

Habitat: Milk and Emmental cheese.

30. **Streptococcus liquefaciens** Orla-Jensen. (*Micrococcus casei amari* Freudenreich, Landwirtsch. Jahrbuch d. Schweiz, *8*, 1894, 136; *Micrococcus zymogenes* McCallum and Hastings, Jour. Exp. Med., *4*, 1899, 531; Orla-Jensen, The Lactic Acid Bacteria, 1919, 142.)

Note: It is possible that this organism is identical with *Streptococcus liquefaciens* Sternberg, Manual of Bact., 1893, 613. It is probably identical with *Streptococcus apis* Maassen as shown by Hucker, N. Y. Agr. Exp. Station, Tech. Bulls. 143, 40 and 190, 17.

Litmus milk: Acid; coagulated (0.7 to 0.8 per cent of acid formed) Casein is peptonized, giving rise to bitter taste.

Acid formed in dextrose, levulose, galactose, mannose, maltose, lactose, sucrose, dextrin, salicin, glycerol, mannitol and sorbitol. Arabinose, raffinose and starch may or may not be fermented.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Milk and cheese.

31. **Streptococcus apis** Maassen. (Arb. Biol. Abt. f. Land- u. Forstwirthschaft a. K. Gesundheitsamte, *6*, 1908, 53.)

More or less spherical organisms, occurring singly, in pairs and occasionally in short chains. Gram-positive.

Dextrose gelatin colonies: Clear, transparent, liquefying in three days at refrigerator temperature.

Gelatin stab: Saccate liquefaction.

Dextrose agar colonies: Small, circular, grayish, smooth, convex, glistening, friable, entire.

Broth: Moderate turbidity.

Litmus milk: Acid; coagulated; peptonized; reduction of litmus.

Potato: No visible growth.

Acid but no gas in dextrose, levulose, maltose, lactose, sucrose and mannitol.

Habitat: Associated at times with European "foulbrood" of bees, occurring as a secondary invader.

Note: Anaerobic species of streptococci have been described. These are monographed by Prévot, Les streptocoques anaérobies, Paris, 1924, 144 pp. The following species appear in the key given in this monograph: *Micrococcus foetidus* Veillon (Comp. rend. Soc. Biol., 1893, 867); *Streptococcus anaerobius* Krönig *emend.* Natvig (Zent. f. Gyn., *48*, 1924, 150; Natvig, Arch. f. Gyn., 1905, 76); *Streptococcus putridus* Schottmüller (Mitteil, a. d. Grenzgeb. d. Med. u. Chir., *21*, 1910, 450); *Streptococcus micros* Prévot (*Streptococcus anaerobius micros* Lewkowicz, Arch. d. Méd. Expér., 1901,) Prévot, (Les streptocoques anaérobies, Paris, 1924, 16); *Streptococcus intermedius* Prévot (loc. cit., 110); *Streptococcus evolutus* Prévot (Streptococcus "Schwarzenbek," Gräf and Wittneben, Cent. f. Bakt., I Abt., Orig., *44*, 1907, 97); Prévot, (loc. cit., 120.) Also see Prévot, (Ann. Sci. Natur., Sér. Bot. et Zool., *15*, 1933, 23–26.) Received too late for consideration in this edition.

Genus III. **Leuconostoc** *Van Tieghem, 1878 emend. Hucker and Pederson**

Cells normally occurring as spheres. Gram positive. Non-motile. Under certain conditions, such as in acid fruit and vegetables, the cells may lengthen and become pointed or even elongated into a rod.

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*The section covering genus *Leuconostoc* has been submitted to Dr. G. J. Hucker and Dr. C. S. Pederson, New York Agricultural Experiment Station, Geneva, New York, for criticism and suggestions.

Grow on ordinary media, but growth is enhanced by the addition of yeast cells, extract of yeast or other vegetable tissues. Generally produce a limited amount of acid. Rarely curdle milk.

Produce mannitol from fructose. By-products of the fermentation of dextrose include carbon dioxide, lactic acid, acetic acid and ethyl alcohol. Approximately one-fourth of the dextrose fermented is converted to carbon dioxide. Levo-lactic acid is always produced and sometimes dextro-lactic acid. Certain types grow with a characteristic slime formation in sucrose media. Ordinarily do not increase the amount of soluble nitrogen in the medium even after long period of incubation.

Synonyms: *Lactococcus* Beijerinck 1912 (pro parte), *Betacoccus* Orla-Jensen 1919.

The type species is: *Leuconostoc mesenteroides* (Cienkowski) Van Tieghem.

Key to species of genus **Leuconostoc.**

A. Acid from sucrose.
B. Acid from pentoses.
1. *Leuconostoc mesenteroides.*
BB. No acid from pentoses.
2. *Leuconostoc dextranicum.*
AA. No acid from sucrose.
3. *Leuconostoc citrovorum.*

1. **Leuconostoc mesenteroides** (Cienkowski) Van Tieghem. (*Ascococcus mesenteroides* Cienkowski, Charkow, 1878; *Leuconostoc mesenteroides* Van Tieghem, Ann. d. Sciences nat., *6*, Sr. 7, 1878, 170; *Leuconostoc aller* Zettnow, Zeitschr. f. Hyg., *57*, 1907, 154; *Leuconostoc opalanitza* Zettnow, loc. cit.; *Betacoccus arabinosaceus* Orla-Jensen, The Lactic Acid Bacteria, 1919; *Bacillus pleofructi* Savage and Hunwicke, Spec. Rept. Food Investigation Board, London, 1823, 134; *Leuconostoc pleofructi* Pederson, N. Y. Agr. Exp. Sta., Tech. Bulls. 150 and 151, 1929.

Spheres: 0.9 to 1.2 microns in diameter occurring in pairs and short or long chains. In sugar solutions the chains are surrounded by a thick, gelatinous, colorless membrane consisting of dextran. Gram positive.

Dextrose gelatin colonies: Small white to grayish-white, raised, nodular.

Dextrose gelatin stab: Growth along entire stab. No liquefaction.

Sucrose broth: Abundant growth with massive formation of slimy material.

Acid formed from dextrose, levulose, galactose, mannose, xylose, arabinose, sucrose, and generally from lactose, raffinose, salicin, mannitol. Rarely acid from dextrin, starch, inulin, sorbitol, rhamnose or glycerol.

Potato: No visible growth.

Indol is not formed.

Nitrates are not reduced.

Produces slime from sucrose. Most pronounced in sucrose gelatin stab.

Aerobic, facultative.

Optimum growth temperature 21°C.

Habitat: Most active of the genus. Generally encountered in vegetable and other plant materials. Frequently isolated from slimy sugar solutions.

2. **Leuconostoc dextranicum** (Beijerinck) Hucker and Pederson. (*Lactococcus dextranicus* Beijerinck, Folia Microbiologica, Delft, 1912, 377; *Betacoccus bovis* Orla-Jensen, The Lactic Acid Bacteria, Copenhagen, 1919; *Streptococcus paracitrovorus* Hammer, Research Bul. *63*, Iowa Agr. Exp. Sta., 1920; Hucker and Pederson, N. Y. Agr. Exp. Sta. Tech. Bull. 167, 1930, 67.)

Note: The description of Streptococcus b, v. Freudenreich (Cent. f. Bakt., II Abt., *3*, 1897, 47), renamed *Streptococcus kefir* by Migula (System der Bakterien, 1900, 44) is too indefinite to permit the determination of its exact relationship to the organisms in this genus. It is clear, however, that the *Streptococcus kefir* of these authors and that of Evans (Jour. Agr. Res., *13*, 1918, 235) were very similar to if not identical with *Leuconostoc dextranicum.*

Spheres: 0.6 to 1.0 microns in diameter, occurring in pairs and in short chains. Gram positive.

Gelatin stab: Gray filiform growth in stab.

Agar colonies: Small, gray, circular, slightly raised, entire.

Dextrose broth: Slight grayish sediment.

Litmus milk: Acid, coagulation. Frequently shows slight reduction of litmus in bottom of tube.

Potato: No visible growth.

Indol is not formed.

Nitrates are not reduced.

Produce slime from sucrose in rapidly growing cultures.

Acid formed from dextrose, levulose, galactose, maltose, sucrose, and generally from lactose and mannose.

No acid formed from xylose, arabinose, glycerol, rhamnose, sorbitol, mannitol, starch, rarely raffinose, inulin, dextrin.

Aerobic, facultative.

Optimum temperature of growth 21° to 25°C.

Habitat: Found both in plant materials and in milk products.

3. **Leuconostoc citrovorum** (Hammer) Hucker and Pederson. (*Streptococcus citrovorus* Hammer, Research Bull. No. 63, Iowa Agr. Exper. Sta., 1920; Hucker and Pederson, N. Y. Agr. Exp. Sta., Tech. Bull. 167, 1930, 67.)

Spheres: 0.6 to 1.0 microns in diameter, occurring in pairs and chains Gram positive.

Gelatin stab: Filiform growth in stab. No liquefaction.

Agar colonies: Small, gray, entire, slightly raised.

Agar slant: Small, gray, discrete colonies.

Dextrose broth: Slight gray sediment.

Litmus milk: Slightly acid with reduction of litmus.

Potato: No visible growth.

Indol is not formed.

Nitrates are not reduced.

Grows poorly on ordinary media without the addition of yeast extract or other growth accessory substance. Forms acid from dextrose, levulose, galactose and lactose.

Generally do not form acid from mannose, sucrose, maltose, xylose, arabinose, rhamnose, raffinose, glycerol, dextrin, inulin, starch, salicin, mannitol or sorbitol.

Uses citric acid in milk.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Found in milk and dairy products.

TRIBE II. NEISSERIEAE COMMITTEE S. A. B., 1920.

Strict parasites, some species failing to grow or growing poorly on usual culture media. Gram stain negative. Growth fairly abundant on serum media. Cells normally in pairs.

Key to the genera of tribe **Neisserieae.**

Grow best at 37°C. Some species show no growth at 20°C. Occur usually as pairs. Colonies may have distinct crumbs scattered on surface.
Genus IV. *Neisseria.*

Genus IV. Neisseria *Trevisan, 1885.*

Characters, those of the tribe.

The type species is *Neisseria gonorrhoeae* Trevisan.

Key to the species of genus **Neisseria.**

1. Grow best on special culture media containing blood, blood serum, or starch, or on plain agar with vitamin. Grow only at 37°C.
   - a. Grow best on media containing serum or starch.
     1. *Neisseria gonorrhoeae.*
   - aa. Grow best on media containing blood or serum.
     2. *Neisseria intracellularis.*
2. Grow well on ordinary culture media. Grow well at 22°C.
   - a. Non-chromogenic
     - b. Moist colonies on agar.
       3. *Neisseria catarrhalis*
     - bb. Dry crumbly colonies on agar.
       4. *Neisseria sicca*

aa. Chromogenic
- b. Acid from levulose.
  - c. Acid from sucrose.
    - 5. *Neisseria perflava*
  - cc. No acid from sucrose.
    - 6. *Neisseria flava*
- bb. No acid from levulose.
  - c. Acid from dextrose.
    - 7. *Neisseria subflava*
  - cc. No acid from dextrose.
    - 8. *Neisseria flavescens.*

1. **Neisseria gonorrhoeae** Trevisan. (Micrococcus der Gonorrhoe, Neisser, Vorl, Mitteil., Cent. f. Medicinische Wissenschaft, *17*, 1879, 497; Trevisan, Atti della Accademia Fisio-Medico-Statistico in Milano, Ser. 4, *3*, 1885, 105.)

Synonyms. Gonococcus, Diplococcus der Gonorrhoe Bumm, Der Mikroorganismen der gonorrhoischen Schleimhauterkrankung, Weisbaden, 1885, 16; *Merismopedia gonorrhoeae* Zopf, Die Spaltpilze, 1885, 54; *Micrococcus gonorrhoeae* Flügge, Die Mikroorganismen, 1886, 156; *Micrococcus gonococcus* Schroeter, Cohn's Kryptogamen Flora von Schlesien, *3*, I, 1886, 147; *Micrococcus gonorhoeae* Lehmann u. Neumann, Atlas u. Grund. d. Bakt., *2*, 1907, 212.

Spheres: 0.6 to 1.0 micron, occurring singly and in pairs, the sides flattened where they are in contact. Gram-negative.

Grow only on special media, as serum-urine agar, ascitic agar or starch agar, or specially prepared plain agar (Thallmann).

Colonies are small, translucent, finely granular with lobate margin, grayish-white with a pearly opalescence by transmitted light.

Forms acid in dextrose media only.

Aerobic, facultative.

Optimum temperature 37°C.

Common name: Gonococcus.

Habitat: The cause of gonorrhoeal infection.

2. **Neisseria intracellularis** (Lehmann and Neumann) Holland. (*Diplococcus intracellularis meningitidis* Weichselbaum, Fortschr. der Medicin, 1887, 573; *Streptococcus intracellularis* Lehmann u. Neumann, Atlas und Grundriss der Bakteriologie, 2, 1896, 132; *Micrococcus intracellularis* Migula, System der Bakterium, 1900, 189; Holland, Jour. of Bact., *5*, 1920, 224. See also Elser and Hunton, Jour. of Medical Res., *20* (N. S. *15*), 1909, 371 and Murray, Med. Res. Council, Special Report Series, 124, 1929, for detailed studies of the group.)

Spheres: 0.6 to 0.8 micron in diameter, occurring singly, in pairs, or occasionally in tetrads. Gram-negative.

Best growth is obtained on media containing blood, blood serum, ascitic fluid or hydrocele fluid.

Blood agar plates are generally employed to isolate the organism. The colonies are small, slightly convex, transparent, glistening.

Older cultures show good growth on neutral agar or dextrose agar, properly prepared. Frequent transplantation is necessary to keep the organism alive in recently isolated strains; older strains survive for one month or longer at 37°C.

Acid formed in dextrose and maltose.

Four main varieties or types of *N. intracellularis* have been differentiated by Gordon and others, on the basis of agglutination reactions with immune serums.

Microaerophilic.

Optimum temperature 37°C.

Common name: Meningococcus.

Habitat: The cause of epidemic meningitis.

3. **Neisseria catarrhalis** (Frosch and Kolle) Holland. (*Micrococcus catarrhalis* Frosch and Kolle in Flügge, Die Mikroorganismen, 3 Aufl., *2*, 1896, 154; *Diplococcus pharyngis communis* v. Lingelsheim, Klin. Jahrb., *15*, 1906, 408; Holland, Jour. Bact., *5*, 1920, 224.)

Spheres: 0.6 to 0.8 micron in diameter, occurring singly or in pairs, occasionally in fours. Gram-negative.

Agar colonies: Small, circular, grayish-white to dirty-white, with erose margin.

Broth: Turbid, often with slight pellicle.

Litmus milk: Unchanged.

Potato: No growth.

No acid formed in any of the carbohydrate media.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Mucous membrane of the respiratory tract. Often associated with other organisms in inflammations of the mucous membrane.

4. **Neisseria sicca** (v. Lingelsheim) Bergey et al. (*Diplococcus pharyngis siccus* v. Lingelsheim, Klin, Jahrb., *15*, 1906, 409; *Diplococcus siccus* v. Lingelsheim, Zeitschr. f. Hyg., *59*, 1908, 476; *Micrococcus pharyngis siccus* Kutscher in Kolle and Wassermann, Handbuch der Pathogenen Mikroorganismen, 2 Aufl., *4*, 1912, 603; *Neisseria pharyngis-sicci* Holland, Jour. of Bact., *5*, 1920, 224; Bergey et al., Manual, 1st ed., 1923, 43.)

Spheres: 0.6 to 0.8 micron in diameter, occurring singly and in pairs. Gram-negative.

Blood agar colonies: Grayish, somewhat dry, crumbling when an effort is made to remove them.

Ascitic agar colonies: Small, very firm and adherent to medium, becoming corrugated on the surface.

Suspended in normal salt solution the organisms sediment spontaneously.

Acid formed in dextrose, levulose, maltose and sucrose. No action on galactose, lactose, inulin, mannitol or dulcitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Normal and inflamed mucous membrane of the respiratory tract.

5. **Neisseria perflava** Bergey et al. (Chromogenic group I, Elser and Huntoon, Jour. of Med. Research, *20* (N. S. *15*), 1909, 415; Bergey et al., Manual, 1st ed., 1923, 43.)

Spheres, 0.6 to 0.8 micron, occurring singly and in pairs. Gram-negative.

Dextrose agar colonies: Small, circular, slightly raised, greenish-gray by reflected light, and greenish-yellow and semiopaque by transmitted light. The surface is smooth, glistening. The growth is adherent to the medium.

Ascitic agar colonies: Like those on dextrose agar.

Acid formed in dextrose, maltose, levulose and sucrose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Mucous membrane of respiratory tract.

6. **Neisseria flava** Bergey et al. (*Diplococcus pharyngis flavus I* and possibly *Diplococcus pharyngis flavus II* v. Lingelsheim, Klin. Jahrb., *15*, 1906, 409; *Diplococcus flavus I* and possibly *Diplococcus flavus II* v. Lingelsheim, Zeitschr. f. Hyg., *59*, 1908, 476; *Micrococcus pharyngis flavus I* and possibly *Micrococcus pharyngis flavus II* Lehmann and Neumann, Bakteriologische Diagnostik, 7 Aufl., *2*, 1927, 259; Chromogenic group II, Elser and Huntoon, Jour. Med. Res., *20* (N. S. *15*), 1909, 415; Bergey et al., Manual, 1st ed., 1923, 43.)

Spheres: 0.6 to 0.8 micron, occurring singly and in pairs. Gram-negative.

Dextrose agar colonies: Small, circular, slightly raised, greenish-gray by reflected light and greenish-yellow by transmitted light. Growth not adherent to medium. Surface colony is smooth with numerous, rather coarse "crumbs" in center. Margin entire, or rarely slightly irregular.

Ascitic agar colonies: Like those on dextrose agar.

Acid formed in dextrose, levulose and maltose. No action on galactose, lactose, sucrose, inulin, mannitol or dulcitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Mucous membrane of respiratory tract.

7. **Neisseria subflava** Bergey et al. (Chromogenic group III, Elser and Huntoon, Jour. Med. Research, *20* (N. S. *15*), 1909, 415; Bergey et al., Manual, 1st. ed., 1923, 44.)

Spheres 0.6 to 0.8 micron, occurring singly and in pairs. Gram-negative.

Dextrose agar colonies: Small, slightly raised, greenish-yellow, resembling those of *N. perflava*.

Acid formed in dextrose and maltose. No action on levulose, sucrose, lactose, galactose, dextrin, inulin, mannitol or dulcitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Mucous membrane of the respiratory tract.

8. **Neisseria flavescens** Branham. (U. S. Public Health Service, Pub. Health Repts., *45*, 1930, 845.)

Biscuit shaped cocci occurring in flattened pairs. Giant forms common. Gram-negative.

Dextrose agar: Poor growth.

Blood agar: Good growth, colonies less moist than those of the meningococcus. Golden yellow pigment.

Semisolid agar: Good growth.

No action on dextrose, levulose, maltose and sucrose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Spinal fluid of cases of meningitis.

Possibly related to *Micrococcus pharyngis cinereus* v. Lingelsheim (Klin. Jahrb., *15*, 1906, 373). However the latter species is reported by Lehmann and Neumann (Bakt. Diag., 7 Aufl., *2*, 1927, 258) to show a white or gray growth.

Note: Wilson and Smith (Jour. Path. and Bact., *31*, 1928, 597) do not regard differences in sugar fermentations chromogenesis, appearance of colonies, etc. sufficiently constant to warrant the separation of the species *Neisseria catarrhalis, N. flava, N. cinerea, N. mucosa* and *N. sicca.* They recommend that all be grouped under a single species known as *N. pharyngis* (*Diplococcus pharyngis*).

TRIBE III. MICROCOCCEAE DE TONI AND TREVISAN, 1889.

Facultative parasites or saprophytes. Thrive best under aerobic conditions. Grow well on artificial media, producing abundant surface growth. Planes of fission often at right angles occurring singly and in pairs and in cell aggregates of groups or packets. Generally stained by Gram. Many species form yellow or red pigment.

Key to the genera of tribe Micrococceae

I. Usually parasitic. Cells occur singly, in pairs and in irregular groups dividing in one or two planes at right angles to each other or in irregular planes. Gelatin is liquefied. Some of the simple carbohydrates are fermented with the formation of acid. Grow best at 37°C.

Genus V. *Staphylococcus*, p. 73.

II. Cells occur in animal body and in special culture media as tetrads; in ordinary media as pairs. Gelatin not liquefied. Grow best at 37°C.

Genus VI. *Gaffkya*, p. 77.

III. Facultative parasites or saprophytes. Cells in plates or irregular masses (not in packets or chains). Acid may be formed in dextrose and in lactose by some species. Gelatin may or may not be liquefied.

Genus VII. *Micrococcus*, p. 78.

IV. Saprophytes or facultative parasites. Division occurs, under favorable conditions, in three planes resulting in the formation of packets. Acid may be formed in dextrose. Lactose usually is not attacked. Gelatin is frequently liquefied.

Genus VIII. *Sarcina*, p. 101.

V. Saprophytes. Cells in groups or in irregular packets. Slight acidity is produced in dextrose but none in lactose. Gelatin is rarely liquefied. Form red pigment.

Genus IX. *Rhodococcus*, p. 106.

Genus V. Staphylococcus *Rosenbach, 1884.*

Usually parasitic, cells occur singly, in pairs and in irregular groups, rarely in packets. Usually Gram-positive. Growth fair to good on the surface of artificial media. As a rule carbohydrates are fermented with the formation of acid. Gelatin commonly liquefied. Nitrates may or may not be reduced. Produce hemolysis on blood agar. Pigment white or orange, or less commonly lemon-yellow.

The type species is *Staphylococcus aureus* Rosenbach.

Key to the species of genus Staphylococcus.

I. Orange pigment.
 1. Lactose fermented. Gelatin liquefied.
 1. *Staphylococcus aureus.*

II. Lemon-yellow pigment.
 1. Lactose fermented. Gelatin liquefied.
 2. *Staphylococcus citreus.*

III. White or colorless growth on solid media.
 1. Lactose fermented. Gelatin liquefied.
 a. Ferment sucrose but not mannitol or raffinose.
 3. *Staphylococcus epidermidis.*
 aa. Ferment sucrose and mannitol but not raffinose.
 b. Found on skin and mucous membranes.
 4. *Staphylococcus albus.*
 bb. Found in house flies.
 5. *Staphylococcus muscae.*
 aaa. Ferment sucrose, mannitol and raffinose.
 6. *Staphylococcus pharyngis.*

1. **Staphylococcus aureus** Rosenbach. (Mikroorganismen bei den Wundinfectionskrankheiten des Menschen, Wiesbaden, 1884, 27; *Staphylo-*

coccus pyogenes aureus Rosenbach, *ibid.; Micrococcus pyogenes aureus* Migula, in Engler and Prantl, Die natlürichen Pflanzenfamilien, I Teil, Abt. 1a, 1895, 16; *Micrococcus aureus* Migula, System der Bakterien, *2*, 1900, 135; *Aurococcus aureus* Winslow and Winslow, The Systematic Relationships of the Coccaceae, 1908, 183.)

Spheres: 0.8 to 1.0 micron, occurring singly, in pairs and in irregular clumps. Gram-positive.

Gelatin stab: Saccate liquefaction with yellowish pellicle and yellow to orange sediment.

Agar colonies: Circular, smooth, yellowish to orange, glistening, butyrous, entire.

Agar slant: Abundant, opaque, smooth, flat, moist, yellowish to orange.

Broth: Turbid with yellowish ring and sediment, becoming clear.

Litmus milk: Acid; coagulated.

Potato: Abundant, orange, glistening.

Indol not formed.

Nitrates reduced to nitrites.

Acid in dextrose, lactose, sucrose and mannitol, but not in raffinose, salicin or inulin.

Slight H_2S formation.

Ammonium salts are not utilized.

Pathogenic.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Skin and mucous membranes. The cause of boils, abscesses, furuncles, suppuration in wounds, etc.

2. **Staphylococcus citreus** (Migula) Bergey et al. (*Staphylococcus pyogenes citreus* Passet, Aetiologe der eiterigen phlegmone des Menschen, Berlin, 1885, 9; *Micrococcus citreus* Migula, System der Bakterien, 1900, p. 147; Manual, 1st ed., 1923, 55.)

Spheres: 0.9 micron, occurring singly. Gram-positive.

Gelatin colonies: Circular, pale yellow, granular, entire, liquefying in 6 days.

Gelatin stab: Lemon yellow surface growth sinking into the medium. Grayish-white growth in stab. Complete liquefaction in 43 days.

Agar colonies: Small, yellow, smooth, entire.

Agar slant: Broad, lemon yellow, glistening, elastic.

Broth: Turbid, with yellow sediment and pellicle.

Litmus milk: Acid, with slow coagulation.

Potato: Thin, grayish streak, becoming citron yellow.

Indol not formed.

Nitrates reduced to nitrites.

Acid in dextrose, lactose, sucrose, raffinose, inulin, salicin, glycerol and mannitol.

Ammonium salts are not utilized.

Pathogenic.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Skin and mucous membranes. Fish skin.

3. **Staphylococcus epidermidis** Bergey et al. (*Staphylococcus epidermidis albus* Welch, Am. Jour. of Med. Sci., Phila., 1891, 439; Bergey et al., Manual, 1st. ed., 1923, 55.)

Note: Not *Albococcus epidermidis* Kligler, Jour. Infect. Dis., *12*, 1913, 444; not *Micrococcus epidermidis* Hucker, N. Y. Agr. Exp. Sta., Tech. Bull. 102, 1924, 21.

The name *Staphylococcus epidermidis* Holland (Jour. Bact., *5*, 1920, 225) is a *nominum nudum* in that no indication is given whether the organism in question is *Staphylococcus epidermidis albus* Welch or *Albococcus epidermidis* Kligler.

Spheres: 0.5 to 0.6 micron, occurring singly, in pairs and in irregular groups. Gram-positive.
Gelatin stab: White surface growth with slow saccate liquefaction.
Agar colonies: Rather scant, white, translucent.
Broth: Turbid, with white ring and sediment.
Litmus milk: Acid.
Potato: Limited growth, white.
Indol not formed.
Nitrates are reduced.
Acid formed in dextrose, levulose, maltose, lactose and sucrose, but not in mannitol, raffinose, salicin or inulin.
Parasitic.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Skin and mucous membranes. Frequently causes "stitch" abscesses.

4. **Staphylococcus albus** Rosenbach. (Microorganismen bei den Wundinfectionskrankheiten des Menschen, Wiesbaden, 1884, 27; also *Staphylococcus pyogenes albus* Rosenbach, ibid.; *Micrococcus pyogenes albus* Migula in Engler and Prantl, Die natürlichen Pflanzenfamilien, I Teil, Abt. 1a, 1895, 16; *Micrococcus pyogenes* Migula, System der Bakterien, *2*, 1900, 87; *Albococcus pyogenes* Winslow and Winslow, The Systematic Relationships of the Coccaceae, 1908, 194; *Micrococcus albus* Buchanan, Veterinary Bacteriology, 1911, 196.)

Spheres: 0.6 to 0.8 micron, occurring singly, in pairs and in irregular groups. Gram-positive.
Gelatin stab: Saccate liquefaction with heavy white sediment.
Agar colonies: Circular, white, smooth, glistening, entire.
Agar slant: Abundant, white, smooth, glistening.
Broth: Turbid, with delicate pellicle and white sediment.
Litmus milk: Acid; coagulated.
Potato: Thick, smooth, white, glistening.

Indol not formed.
Nitrates may or may not be reduced.
H_2S is formed.
Acid formed in dextrose, lactose, sucrose and mannitol, but not in raffinose, salicin and inulin.
Ammonium salts are not utilized.
Pathogenic.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Skin and mucous membranes. Occurs in wounds, boils, abscesses, etc.

5. **Staphylococcus muscae** Glaser (Am. Jour. Hyg., *4*, 1924, 411).
Spheres: 0.5 to 1.0 microns in diameter, occur singly and in pairs. Non-motile. Gram-positive.
Gelatin stab: Slow infundibuliform liquefaction.
Agar colonies: Circular, white, smooth, amorphous, flat.
Agar slant: Abundant, white, echinulate, smooth, glistening, opaque.
Broth: Turbid with ring formation. Abundant, viscid sediment.
Litmus milk: Slightly acid, slow coagulation.
Potato, Abundant, white.
Indol is not formed.
Nitrates.
Acid formed in dextrose, lactose, sucrose and mannitol.
Habitat: Causes fatal infection in house flies. Transmissible to healthy flies.

6. **Staphylococcus pharyngis** Bergey et al. (Manual, 1st ed., 1923, 56.)
Spheres: 0.6 to 0.8 micron, occurring singly and in pairs. Gram-positive.
Gelatin stab: Liquefaction crateriform becoming stratiform, with white sediment.
Agar colonies: White, raised, slimy, smooth, glistening, entire.
Agar slant: Abundant, white, smooth, glistening.
Broth: Turbid with white ring and sediment.
Litmus milk: Acid; coagulated.
Potato: Abundant, white, smooth, slimy.
Indol not formed.
Nitrates reduced to nitrites.
Acid in dextrose, lactose, sucrose, raffinose, salicin and mannitol, but not in inulin.
Pathogenic.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from the nasopharynx in acute catarrhal inflammation.

Note: The staphylococci have been divided into several groups on the basis of agglutinin absorption tests. Julianelle (Jour. Infect. Dis., *31*,

1922, 256) was able to differentiate three main groups and two subgroups. These groups do not conform strictly with differences in pigment formation and other biologic characters. Hine (The Lancet, *203*, 1922, 1380) divides the staphylococci into two main groups on the basis of biologic characters: *Staphylococcus pyogenes* (*S. aureus*, *S. albus*, *S. citreus*) and *S. epidermidis* groups. As a rule, those of the *S. pyogenes* group ferment mannitol, and those of the *S. epidermidis* group do not. As a rule also, those of the *S. epidermidis* group are white, though pigment forming strains were encountered. By agglutinin absorption tests, he was able to distinguish three types in the *S. pyogenes* group and two types in the *S. epidermidis* group.

It is probable that the salicin fermenting strains (*S. pharyngis*) form distinct serologic types from the *S. pyogenes* and *S. epidermidis* groups.

Genus VI. **Gaffkya** *Trevisan, 1885.*

Parasitic organisms, occurring in the animal body and in special media as tetrads, while in ordinary culture media they occur in pairs and irregular masses. Gram-positive.

The type species is *Gaffkya tetragena* (Gaffky) Trevisan.

1. **Gaffkya tetragena** (Gaffky) Trevisan. (*Micrococcus tetragenus* Gaffky, Arch. f. Chirurg., *28*, 1883, 500; Trevisan, Atti d. Accad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 106; *Staphylococcus tetragenus* Bergey et al., Manual, 1st ed., 1923, 56.)

Spheres: 0.6 to 0.8 micron in size, with pseudocapsule (in body fluids) surrounding four of the elements showing typical tetrads. Gram-positive.

Gelatin colonies: Small, 1 to 2 mm. in diameter, white, convex.

Gelatin stab: Thick, white surface growth. No liquefaction.

Agar colonies: Circular, white, smooth, glistening, entire.

Agar slant: White, moist, glistening.

Broth: Clear, with gray viscous sediment.

Litmus milk: Slightly acid.

Potato: White, viscid.

Indol not formed.

Nitrates not reduced.

Acid in dextrose and lactose.

H_2S not formed.

Aerobic, facultative.

Pathogenic for mice and guinea pigs; rabbits less susceptible.

Optimum temperature 37°C.

Habitat: Mucous membrane of respiratory tract. Isolated from sputum in tuberculosis; also from air and skin.

2. **Gaffkya tardissima** (Altana) Bergey et al. (*Tetragenus tardissimus* Altana, Cent. f. Bakt., I Abt., Orig., *48*, 1909, 42; Manual, 2nd ed., 1925, 59.)

Small oval forms grouped in fours in the animal body; showing a capsule around the group. The addition of serum to media favors the development of the organism. Gram-positive.

Gelatin colonies: Very small, circular, brownish by reflected light, coarsely granular under the microscope.

Gelatin stab: Very slow and poor development. No liquefaction.

Agar colonies: Very small, white, granular, circular, entire.

Agar slant:

Broth: Fine, granular sediment.

Litmus milk: Unchanged.

Potato: No visible growth.

Indol not formed.

Dextrose is not fermented.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: In natural infection of guinea pigs.

3. **Gaffkya verneti** Corbet (Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 143).

Spheres, ranging from 0.5 to 1.0 micron in diameter, occurring in groups of four. Non-motile. Gram-positive.

Gelatin stab: Liquefied.

Agar colonies: Circular, pale yellow.

Agar slant: Moderate growth, beaded, pale yellow, flat, dull.

Broth: Slight turbidity and sediment.

Litmus milk: Unchanged.

Potato:

Indol is not formed.

Nitrates are not reduced.

No action on carbohydrates.

Ammonia is produced.

Aerobic.

Optimum temperature 30°C.

Resists heating to 85°C. for 10 minutes.

Habitat: Isolated from the latex of *Hevea brasiliensis*.

Genus VII. **Micrococcus** *Cohn, 1872.*

Facultative parasites or saprophytes. Cells in plates or irregular masses (never in long chains or packets). Generally stained by Gram. Growth on agar usually abundant, some species form no pigment but others form yellow or less commonly, orange pigment. Dextrose broth slightly acid, lactose broth generally neutral. Gelatin frequently liquefied, but not rapidly.

The type species is *Micrococcus luteus* (Schröter) Cohn.

Key to the species of genus **Micrococcus.**

A. Aerobic species.

I. Pigment yellow or orange.

1. Gelatin not liquefied.

a. Milk generally slightly acid; not coagulated.
b. Citron-yellow growth on potato.
c. Nitrates not reduced.
1. *Micrococcus luteus.*
2. *Micrococcus aurantiacus.*
cc. Nitrates reduced.
3. *Micrococcus varians.*
aa. Milk unchanged.
b. Yellow growth on potato.
c. Nitrates not reduced.
4. *Micrococcus cereus.*
5. *Micrococcus pikowskyi.*
bb. No growth on potato.
c. Nitrates not reduced.
6. *Micrococcus ochraceus.*
7. *Micrococcus xenopus.*
aaa. Milk becoming slimy.
b. Gray growth on potato.
c. Nitrates not reduced.
8. *Micrococcus pituitoparus.*
aaaa. Milk shows bluish-green luminescence.
b. Greenish growth on potato.
c. Nitrates not reduced.
9. *Micrococcus phosphorescens.*
aaaaa. Milk alkaline.
b. Growth on potato not recorded.
c. Nitrates are reduced.
10. *Micrococcus eatonii.*
11. *Micrococcus ridleyi.*
2. Gelatin liquefaction saccate to infundibuliform.
a. Milk acid, with slow coagulation.
b. Yellow growth on potato.
c. Nitrates not reduced.
12. *Micrococcus mucofaciens.*
cc. Nitrates reduced.
13. *Micrococcus caseolyticus.*
aa. Milk alkaline; slowly peptonized.
b. No growth on potato.
c. Nitrates not reduced.
14. *Micrococcus subflavescens.*
aaa. Milk unchanged.
b. Yellow growth on potato.
c. Nitrates not reduced.
15. *Micrococcus flavescens.*
3. Gelatin liquefaction crateriform to stratiform.
a. Milk acid, with slow coagulation.

b. Yellow growth on potato.
c. Nitrates not reduced.
16. *Micrococcus flavus.*
bb. Orange growth on potato.
c. Nitrates reduced to nitrites.
17. *Micrococcus perflavus.*
aa. Milk alkaline; slowly peptonized.
b. Yellow growth on potato.
c. Nitrates not reduced.
18. *Micrococcus subflavus.*
bb. White growth on potato.
c. Nitrates not reduced.
19. *Micrococcus sensibilis.*
bbb. No growth on potato.
c. Nitrates reduced to nitrites.
20. *Micrococcus percitreus.*
aaa. Milk unchanged.
b. Yellow growth on potato.
c. Nitrates not reduced.
21. *Micrococcus subcitreus.*
22. *Micrococcus luteolus.*
bb. No growth on potato.
c. Nitrates not reduced.
23. *Micrococcus subgranulatus.*
cc. Nitrates reduced to nitrites.
24. *Micrococcus conglomeratus.*

II. No pigment formed.
1. Gelatin liquefied
a. Milk acid; coagulated; peptonized.
b. Yellow-white growth on potato.
c. Nitrates not reduced.
25. *Micrococcus freudenreichii.*
bb. White growth on potato.
c. Nitrates not reduced.
26. *Micrococcus cremoris-viscosi.*
aa. Milk alkaline.
b. White growth on potato.
c. Nitrates not reduced.
27. *Micrococcus saccatus.*
2. Gelatin not liquefied.
a. Milk slightly acid; no coagulation.
b. White growth on potato.
c. Nitrates not reduced.
28. *Micrococcus candidus.*

bb. Yellow-white growth on potato.
c. Nitrates not reduced.
29. *Micrococcus candicans.*
aa. Milk acid, coagulated.
b. Growth on potato not recorded.
c. Nitrates are reduced.
30. *Micrococcus epimetheus.*
aaa. Milk becoming slimy.
b. Grayish-white growth on potato.
c. Nitrates not reduced.
31. *Micrococcus viscosus.*
aaaa. Milk slightly alkaline.
b. Grayish-white growth on potato.
c. Nitrates not reduced.
32. *Micrococcus ureae.*
aaaaa. Milk unchanged.
b. Yellow-brown growth on potato.
c. Nitrates reduced.
33. *Micrococcus nitrificans.*
bb. White growth on potato.
c. Nitrates not reduced.
34. *Micrococcus chersonesia.*
35. *Micrococcus halophilus.*
36. *Micrococcus spheroides.*
37. *Micrococcus piltonensis.*

B. Anaerobic species.

I. No pigment formed.

1. Gelatin not liquefied.
a. Gas formed in milk.
b. Grayish-white growth on potato.
c. Nitrates not reduced.
38. *Micrococcus buccalis.*
bb. No growth on potato.
c. Nitrates not reduced.
39. *Micrococcus gingivalis.*
cc. Nitrates reduced.
40. *Micrococcus gasogenes.*
aa. No gas formed in milk.
b. No growth on potato.
c. Nitrates not reduced.
41. *Micrococcus minimus.*
cc. Nitrates reduced.
42. *Micrococcus syzygios.*
aaa. No growth in milk.

b. Acid in dextrose.

43. *Micrococcus parvulus.*

44. *Micrococcus branhamii.*

bb. No acid in dextrose.

45. *Micrococcus reniformis.*

II. Yellow pigment formed.

1. Gelatin not liquefied.

a. Milk unchanged.

b. No growth on potato.

c. Nitrates not reduced.

46. *Micrococcus aerogenes.*

1. **Micrococcus luteus** (Schröter) Cohn. (*Bacteridium luteum* Schröter, Beiträge z. Biol. d. Pflan., *1* (Heft 2), 1872, 119; Cohn, ibid., 153.)

Spheres: 1.0 to 1.2 microns, occurring in pairs and fours. Gram-positive.

Gelatin colonies: Yellowish-white to yellow, raised, with undulate margin.

Gelatin stab: No liquefaction.

Agar colonies: Small, yellowish, glistening, raised.

Agar slant: Citron-yellow, smooth.

Broth: Clear, with yellowish sediment.

Litmus milk: Usually slightly acid, not coagulated.

Potato: Thin, glistening, citron-yellow growth

Indol not formed.

Nitrates not reduced.

Acid in dextrose, sucrose and mannitol.

Ammonium salts are utilized.

Aerobic.

Optimum temperature 25°C.

Habitat: Air and water.

2. **Micrococcus aurantiacus** (Schröter) Cohn. (*Bacteridium aurantiacum* Schroeter, Beiträge z. Biologie, *1*, Heft II, 1872, 126; Cohn, Beiträge z. Biologie, *1*, Heft II, 1872, 154; *Micrococcus aurantiacus-sorghi* Bruyning, Arch. Néer. Sci. Exact. et Nat., *1*, 1898, 297; *Streptococcus aurantiacus* Chester, Manual, 1901, 69; *Aurococcus aurantiacus* Winslow and Winslow, The Systematic Relationships of the Coccaceae, 1908, 186.

Spheres: Slightly oval, 1.3 to 1.5 microns, occurring singly and in small clumps. Gram-positive.

Gelatin colonies: Circular to oval, smooth, glistening with yellow to orange center.

Gelatin stab: Yellow surface growth. No liquefaction.

Agar colonies: Circular, smooth, glistening, yellow to orange, entire.

Agar slant: Buff to scant orange-yellow, beaded growth, raised, glistening.

Broth: Turbid, with pellicle.
Litmus milk: Faintly acid, no coagulation.
Potato: Slimy, yellow growth. Pigment is insoluble in alcohol and ether.
Indol not produced.
Nitrates not reduced (occasionally a trace).
Slight acidity in dextrose, levulose, sucrose and mannitol. No acid in lactose, raffinose, salicin, inulin.
No growth in ammonium media.
Not pathogenic.
Aerobic.
Optimum temperature 25°C.
Habitat: Water and air.

3. **Micrococcus varians** Migula. (*Merismopedia flava varians* Dyar, Annals of the N. Y. Academy of Sciences, *8*, 1895, 346; *Micrococcus lactis varians* Conn, Esten and Stocking, Storrs Agr. Exp. Sta., Rept. for 1906, 121; Migula, System der Bakterien, 1900, 135.)
Spheres: 0.8 to 1.0 micron, occurring singly, in pairs and in fours. Gram-positive.
Gelatin colonies: Small, circular, whitish to yellow, capitate, moruloid.
Gelatin stab: Scant growth.
Agar colonies: Small, yellow, raised, glistening.
Agar slant: Plumose, yellow, variegated.
Broth: Turbid, with yellow, granular sediment.
Litmus milk: Acid; coagulated on boiling.
Potato: Raised, dry, bright-yellow, glistening.
Indol not formed.
Nitrates reduced to nitrites.
Acid in dextrose, lactose, sucrose, raffinose and frequently in glycerol and mannitol. No acid in salicin or inulin.
Ammonium salts are utilized.
Aerobic.
Optimum temperature 25°C.
Habitat: Air, milk, sea water.

4. **Micrococcus cereus** Migula. (*Staphylococcus cereus flavus* Passet, Untersuchungen über die Aetiologie der eiterigen Phlegmone des Menschen, 1885, 53; Migula, System der Bakterien, 1900, 126.)
Spheres: 1.0 micron, occurring singly and in pairs. Gram-positive.
Gelatin colonies: Pale, transparent, becoming yellowish.
Gelatin stab: Yellow, glistening surface growth. No liquefaction.
Agar colonies: Pale yellow, smooth, entire.
Agar slant: Yellow, smooth, glistening.
Broth: Turbid, with yellowish sediment.
Litmus milk: Unchanged.
Potato: Grayish yellow layer, becoming dark, citron yellow.
Indol is not produced.

Nitrates not reduced.
Aerobic.
Optimum temperature 25° to 30°C.
Habitat: Isolated from pus.

5. **Micrococcus pikowskyi** Bergey et al. (Culture No. 22, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Manual, 3rd ed., 1930, 78.)

Spheres: 1.3 to 1.9 microns, occurring singly and in pairs. Gram-positive.
Gelatin stab: Yellowish-white surface growth. No liquefaction.
Agar colonies: Circular, yellowish-white.
Agar slant: Filiform, yellowish-white.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Scant, grayish streak.
Indol is not formed.
Nitrates not reduced.
Ammonia is formed.
H_2S is formed.
Growth occurs in media with 16 per cent NaCl.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Sea water.

6. **Micrococcus ochraceus** Rosenthal. (Inaugural Dissertation, Berlin, 1893, 22.)

Spheres: 0.7 to 0.8 micron, occurring singly and in pairs. Gram-positive
Gelatin colonies: Small, circular, pale yellow.
Gelatin stab: Slight, grayish-yellow growth in stab. No liquefaction.
Agar colonies: Slowly developing, pale yellow, slightly convex, smooth, homogeneous, entire.
Agar slant: Canary yellow, plumose, slightly wrinkled, undulate margin.
Broth: Turbid, with yellow, granular sediment.
Litmus milk: Unchanged.
Potato: Slight, yellowish filiform growth. Sometimes no growth is detected.
Indol is not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 25°C.
Habitat: Air. Isolated from oral cavity.

7. **Micrococcus xenopus** Schrire and Greenfield. (Trans. Royal Soc. So. Africa, *17*, 1930, 309.)

Spheres 1.0 to 1.2 microns. Gram negative.
Gelatin stab: Not liquefied.
Agar colonies: Small, circular, dew-drop, discrete, brittle, entire.

Agar slant:
Broth: Clear.
Litmus milk: Shows reduction.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Acid in dextrose.
Blood serum not peptonized.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from abscess of muscle of frog.

8. **Micrococcus pituitoparus** (Hohl) Buchanan and Hammer. (*Karphococcus* (*Carphococcus*) *pituitoparus* Hohl, Jahrb. der Schweiz, *22*, 1906, 439; *Diplococcus viscosus* Saits, Cent. f. Bakt., II Abt., *19*, 1907; Buchanan and Hammer, Iowa Agr. Exp. Sta., Res. Bul. 22, 1915, 285.)

Spheres ranging from 0.5 to 1.5 microns in diameter, occurring singly, in pairs and in short chains. Gram-positive.

Gelatin colonies: Small, circular, whitish-yellow.
Gelatin stab: Lobulated surface growth. No liquefaction.
Agar slant: Abundant, whitish-yellow, viscous growth.
Broth: Turbid, with gray sediment.
Litmus milk: Slimy with white pellicle.
Potato: Luxuriant, gray, syrupy.
Indol not formed.
Nitrates not reduced.
No acid in carbohydrate media.
Aerobic.
Optimum temperature 20°C.
Habitat: Slimy milk.

9. **Micrococcus phosphoreus** Cohn. (See letter by Cohn addressed to J. Penn, Vergameling van stukken betreffende het geneeskundig staatstoezigt in Nederland, Jaarg. 1878, 126; Schroeter, Cohn's Kryptogamen-Flora von Schlesien, *3*, I, 1886, 146; *Bacterium phosphoreum* Molisch, Die Leuchtende Pflanzen, 1912, 66.)

Large spheres: 1.0 to 2.0 to 7.0 microns, occurring singly. Gram-positive.

Gelatin colonies: Yellowish-white, circular, glistening, with undulate margin.

Gelatin stab: No liquefaction.
Broth: Turbid with whitish flocculent sediment.
Litmus milk: Bluish-green luminescence.
Potato: The growth gives off a strong odor of trimethylamine. Best growth on boiled fish, meat and crabs.
Acid and gas in dextrose media.

Luminescence: Whitish.
Aerobic, facultative.
Optimum temperature 15° to 20°C.
Habitat: Isolated from meat in refrigerators, butcher shops and markets.

10. **Micrococcus eatonii** Corbet. (Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 145.)

Spheres, 1.2 to 1.5 microns in diameter, occurring singly and in irregular masses. Non-motile. Gram-positive.
Gelatin stab: No liquefaction.
Agar colonies: Circular, yellow, opaque.
Agar slant: Moderate growth, filiform, yellow, flat, glistening.
Broth: Slightly turbid with sediment.
Litmus milk: Alkaline, peptonized.
Potato:
Indol is not formed.
Nitrates are not reduced.
No action on carbohydrates.
No digestion of starch.
Ammonia is formed.
Aerobic.
Optimum temperature 30°C.
Habitat: Isolated from the latex of *Hevea brasiliensis.*

11. **Micrococcus ridleyi** Corbet. (Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 146.)

Spheres, 0.6 to 0.7 micron in diameter, occurring in pairs and in irregular masses. Non-motile. Gram-positive.
Gelatin stab: Liquefied.
Agar colonies: White, oval, opaque.
Agar slant: Moderate growth, filiform, raised, moist, pale yellow, glistening.
Broth: Yellow pellicle and sediment, with clear liquid.
Litmus milk: Decolorized.
Potato:
Indol is not formed.
Nitrates are not reduced.
Acid in dextrose.
Ammonia is formed.
Aerobic.
Optimum temperature 30°C.
Habitat: Isolated from the latex of *Hevea brasiliensis.*

12. **Micrococcus mucofaciens** Thöni and Thaysen. (Cent. f. Bakt., II Abt., *36*, 1913, 359.)

Spheres, of variable size, 0.5 to 1.6 microns, occurring singly, in pairs, occasionally in fours. Gram-positive.

Gelatin colonies: Small, gray, becoming light yellow, entire.
Gelatin stab: Slow, saccate liquefaction.
Agar colonies: Small, circular, flat, yellowish-brown, glistening.
Agar slant: Yellowish-brown, raised, glistening.
Broth: Turbid, with viscid sediment.
Litmus milk: Slightly acid, becoming viscid, with yellowish-brown ring.
Potato: Light yellow, soft, glistening, viscid.
Indol not formed.
Nitrates not reduced.
No acid formed in carbohydrate media
Aerobic.
Optimum temperature 35°C.
Habitat: Milk.

13. **Micrococcus caseolyticus** Evans. (Jour. Infect. Dis., *18*, 437–476, 1916; *Micrococcus casei* Hucker, N. Y. State Agric. Exp. Station Tech. Bull. 102. 1924; Probably identical in part with *Tetracoccus liquefaciens* Orla-Jensen, The Lactic Acid Bacteria, 1919.)

Spheres, variable in size, occurring in clumps. Gram-positive.

Gelatin stab: Liquefaction generally begins after first day and continues rapidly.

Agar colonies: Surface colonies raised and pearly white. Deep colonies generally punctiform.

Agar stroke: Luxuriant pearly white growth.

Broth: Generally grows with smooth turbidity although certain strains give heavy precipitate with clear supernatant fluid.

Litmus milk: Acid, peptonized. Whey generally clear.

Potato: Scanty white growth. Certain strains may show a slight tendency to faint yellow pigment.

Indol not formed.

Nitrates reduced.

Acid in dextrose, lactose, maltose, mannitol and glycerol. No action on raffinose.

Utilizes ammonium salts as a source of nitrogen.

Optimum temperature 22°C.

Aerobic.

Habitat: Isolated from udder of cows as well as a variety of dairy products.

14. **Micrococcus subflavescens** Bergey et al. (Manual, 1st ed., 1923, 61.)

Spheres: 1.0 to 1.2 microns, occurring singly and in pairs. Gram-positive.

Gelatin colonies: Yellow, circular, liquefying.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Small, canary-yellow, raised, entire.

Agar slant: Canary-yellow, filiform to plumose, smooth, moist, undulate margin.

Broth: Turbid, with yellowish sediment.
Litmus milk: Alkaline, peptonized. Litmus reduced.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 25°C.
Habitat: Air and water.

15. **Micrococcus flavescens** Henrici. (Arb. a.d. Bakt. Institut d. Techn. Hochschule zu Karlsruhe, *1*, 1894, 79.)

Spheres: 1.5 to 1.8 microns, occurring singly, in pairs and in fours. Gram-positive.
Gelatin colonies: Circular, yellowish, glistening, with undulate margin.
Gelatin stab: Infundibuliform liquefaction.
Agar colonies: Small, yellow, convex, homogeneous, entire.
Agar slant: Canary-yellow, smooth, plumose, moist, undulate.
Broth: Turbid, with yellow sediment.
Litmus milk: Unchanged.
Potato: Yellow, filiform growth.
Indol not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 25°C.
Habitat: Air. Isolated from Swiss cheese.

16. **Micrococcus flavus** Lehmann and Neumann. (*Micrococcus flavus liquefaciens* Flügge, Die Mikroorganismen, 1886, 174; Lehmann and Neumann, Atlas und Grundriss der Bakt, *2*, 1896, 196.)

Spheres: 0.8 to 0.9 micron, occurring singly and occasionally in fours. Gram-positive.
Gelatin colonies: Small, circular, yellowish to yellowish-brown, somewhat serrate margin.
Gelatin stab: Yellow, wrinkled surface growth with slow, crateriform liquefaction.
Agar colonies: Small, pale yellowish, homogeneous, entire.
Agar slant: Canary-yellow, somewhat dry, wrinkled, raised, entire.
Broth: Turbid with yellowish ring and sediment.
Litmus milk: Slightly acid, soft coaglum formed, with slight reduction; slowly peptonized.
Potato: Slight, canary-yellow growth.
Indol is not formed.
Nitrates not reduced.
Starch is hydrolyzed.
Acid is generally formed in dextrose, lactose, sucrose and glycerol.
Ammonium salts are utilized.
Aerobic.

Optimum temperature 25°C.
Habitat: Isolated from air.

17. **Micrococcus perflavus** Bergey et al. (Manual, 1st ed., 1923, 62.)
Spheres: 0.7 to 0.9 micron, occurring singly, in pairs and in fours. Gram-positive.
Gelatin colonies: Small, pale yellow, smooth, entire.
Gelatin stab: Crateriform liquefaction, becoming stratiform.
Agar colonies: Light orange, dull, granular, lobate margin.
Agar slant: Light orange, flat, spreading, somewhat dull, undulate margin.
Broth: Turbid, with gray pellicle and sediment.
Litmus milk: Acid; coagulation. Reduction.
Potato: Orange, filiform, dull, raised.
Indol not produced.
Nitrates reduced to nitrites and ammonia.
Aerobic.
Optimum temperature 25°C.
Habitat: Air and water.

18. **Micrococcus subflavus** Bumm. (Mikroorganismen der Gonorrhöischen Schleimhauterkrankungen, 2 Aufl., 1887, 20.)
Spheres: 0.6 to 0.8 micron, occurring singly and in pairs. Gram-positive.
Gelatin colonies: Very small, yellow, slowly liquefying.
Gelatin stab: Liquefaction crateriform, becoming stratiform.
Agar colonies: Small, greenish, yellow, convex, homogeneous, entire.
Agar slant: Plumose, greenish-yellow, smooth, raised, undulate margin.
Broth: Turbid, with yellowish, fluorescent pellicle and sediment.
Litmus milk: Slightly acid, becoming alkaline with yellow ring and sediment. Undergoes slow digestion.
Potato: Yellow, filiform, raised. Medium discolored.
Indol not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 25°C.
Habitat: Air and water. Isolated from gonorrheal pus.

19. **Micrococcus sensibilis** Zettnow. (Cent. f. Bakt., I Abt., Orig., 77, 1915, 216.)
Spheres: 0.8 to 1.0 micron in diameter, occurring singly. Motile, possessing a single flagellum. Gram-positive.
Gelatin colony: Small, colorless, finely granular, entire.
Gelatin stab: White surface growth. Slow crateriform liquefaction.
Agar slant: White to dirty-yellow streak.
Broth: Turbid.
Litmus milk: Alkaline; peptonized.
Potato: Dirty-white layer, smooth, becoming yellow.

Indol not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 25°C.
Habitat: Air.

20. **Micrococcus percitreus** Bergey et al. (Manual, 1st ed., 1923, 63.)
Spheres: 0.8 to 0.9 micron, occurring singly and in pairs. Gram-positive.
Gelatin stab: Slow crateriform liquefaction, becoming stratiform.
Agar colonies: Circular, pale yellow, smooth, glistening, raised, entire.
Agar slant: Greenish-yellow, plumose, moist, raised, entire.
Broth: Turbid, with grayish-yellow sediment.
Litmus milk: Slightly acid; becoming alkaline. Reduction. Digestion.
Potato: No growth.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic.
Optimum temperature 35°C.
Habitat: Air and water.

21. **Micrococcus subcitreus** Migula. (Citronengelber micrococcus Keck, Ueber das Verhalten der Bakterien im Grundwasser, Dorpat Dissertation, 1890, 60; Migula, System der Bakterien, 1900, 147.)
Spheres: 0.8 to 0.9 micron, occurring singly and in pairs. Gram-positive.
Gelatin colonies: Small, greenish-yellow, circular.
Gelatin stab: Slow crateriform liquefaction.
Agar slant: Greenish-yellow plumose, smooth, moist, raised, undulate margin.
Broth: Turbid, with greenish sediment.
Litmus milk: Unchanged.
Potato: Yellow, moist, smooth, raised, becoming dry.
Indol not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 25°C.
Habitat: Air and water.

22. **Micrococcus luteolus** Irwin and Harrison. (Le Lait, *8*, 1928, 881.)
Spheres: 0.8 to 1.2 microns in size, occurring singly, pairs, chains or groups. Gram-positive.
Gelatin colonies: Small, circular, yellow, dentate margin.
Gelatin stab: Yellow surface growth. Crateriform liquefaction.
Agar colonies: Circular, citron yellow, smooth.
Agar slant: Citron yellow streak, moist, becoming slightly rugose.
Broth: Turbid with yellow, flocculent sediment, the supernatant liquid becoming clear.

Litmus milk: Unchanged.
Potato: Abundant, citron yellow, rugose.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose. No acid in lactose, sucrose or raffinose.
H_2S not formed.
The pigment is insoluble in alcohol and chloroform.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from "process" cheese.

23. **Micrococcus subgranulatus** Freund. (Inaug. Dissertation, Erlangen, 1893, 27.)

Spheres: 0.6 to 0.8 micron, occurring singly and in pairs. Gram-positive.
Gelatin colonies: Circular to irregular, yellow with darker center.
Gelatin stab: Slow crateriform liquefaction.
Agar slant: Yellow, filiform, moist, smooth, raised, entire.
Broth: Turbid, with pale yellow sediment.
Litmus milk: Unchanged.
Potato: Generally fails to grow.
Indol not formed.
Nitrates not reduced.
Starch is not hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Air. Isolated from the oral cavity.

24. **Micrococcus conglomeratus** Migula. (Citronengelber Diplococcus Bumm, Der Mikroorganismen der gonorrhoischen Schleimhauterkrankungen, 1 Aufl., 1885; *Micrococcus citreus conglomeratus* Flügge, Die Mikroorganismen, 1886, 182; *Diplococcus citreus conglomeratus* Bumm, 2 Aufl., 1887; *Merismopedia citreus conglomeratus* Dyar, Ann. New York Acad. Sci., *8*, 1895, 352; *Micrococcus citreus* Winslow and Winslow, The Systematic Relationships of the Coccaceae, 1908, 218; Migula, System der Bakterien, *2*, 1900, 146.)

Spheres: 0.8 to 1.2 microns, occurring singly, in pairs and in fours. Gram-positive.
Gelatin colonies: Small, circular, yellow with radiate margin.
Gelatin stab: Slow crateriform liquefaction.
Agar colonies: Small, pale orange, convex, homogeneous, entire.
Agar slant: Light orange, plumose, slightly rugose, somewhat dull, raised center and transparent margin.
Broth: Turbid, with light orange ring and sediment.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates reduced to nitrites.

Starch is not hydrolyzed.
Ammonium salts are utilized.
Aerobic.
Optimum temperature 25°C.
Habitat: Air; milk; widely distributed.

25. **Micrococcus freudenreichii** Guillebeau. (Landwirtschäftl. Jahresb. d. Schweiz, 1891, 135.)

Synonyms: *Micrococcus acidi lactis* Kruger, Cent. f. Bakt., 7, 1890, 464; *Micrococcus amarafaciens* Migula, System der Bakterien, 1900, 100; *Coccus lactis viscosi* Gruber, Cent. f. Bakt., II Abt., *22*, 401; *Micrococcus lactis albidus* Conn, Esten and Stocking, Conn. (Storrs) Agr. Exp. Sta., 18th Ann. Rpt. for 1906, 91; *Micrococcus lactis viscosus* Sternberg, Manual of Bacteriology, 1893, 604.

Spheres: 0.6 to 1.2 microns in diameter, occurring singly, rarely in short chains. Gram-positive.
Gelatin colonies: Small, white, opaque.
Gelatin stab: Infundibuliform liquefaction.
Agar colonies: White, slimy.
Agar streak: White, smooth.
Broth: Turbid, with white sediment
Litmus milk: Acid; coagulated; peptonized.
Potato: Moderate white to yellow streak.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, lactose and sucrose. Some strains form acid in mannitol; others in glycerol.
Aerobic.
Optimum temperature 20°C.
Habitat: Milk.

26. **Micrococcus cremoris-viscosi** (Hammer and Cordes) Bergey et al. (*Staphylococcus cremoris-viscosi* Hammer and Cordes, Jour. of Dairy Science, *3*, 1920, 291; Bergey et al., Manual, 3rd ed., 1930, 86.)

Spheres: 0.9 to 1.0 micron, occurring singly. Gram-positive.
Whey gelatin stab: Slow, crateriform liquefaction.
Agar colonies: Large, circular, white, viscid, opaque, raised, entire.
Agar slant: Heavy, white, viscid, raised, entire margin.
Broth: Turbid with slight gray sediment.
Litmus milk: Acid, coagulated, ropy, peptonized. Litmus reduced.
Potato: White, moist, viscid, spreading growth.
Indol is not formed.
Nitrates.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Isolated from ropy milk.

27. **Micrococcus saccatus** Migula. (*Micrococcus albus liquefaciens* von Besser, Beiträge z. path. Anatomie, *6*, 1889, 46; Migula, System der Bakterien, 1900, 117; *Micrococcus liquefaciens* Bergey et al., Manual, 1st ed., 1923, 67.)

Spheres: 0.6 by 0.7 to 1.0 micron, occurring in pairs and clumps. Gram-positive.

Gelatin stab: Crateriform to saccate liquefaction.

Agar colonies: Circular, smooth, convex, raised, amorphous, entire.

Agar slant: White, glistening growth.

Broth: Turbid, with viscid sediment.

Litmus milk: Slightly alkaline.

Potato: White to greenish-yellow, glistening growth.

Indol is not formed.

Nitrates not reduced.

Aerobic.

Optimum temperature 25°C.

Habitat: Nasal mucous membrane.

28. **Micrococcus candidus** Cohn. (Beiträge z. Biologie, *1*, Heft II, 1872, 160.)

Spheres: 0.5 to 0.7 micron, occurring singly. Gram-positive.

Gelatin colonies: White, granular, with irregular or entire margin.

Gelatin stab: White surface growth. Filiform. No liquefaction.

Agar colonies: Punctiform, white, smooth, entire, iridescent.

Agar slant: Smooth, white, glistening, iridescent.

Broth: Turbid, with pellicle.

Litmus milk: Slightly acid; not coagulated.

Potato: Thick, porcelain white, glistening.

Indol is not produced.

Nitrates not reduced.

No acid in carbohydrate media.

Non-pathogenic.

Aerobic.

Optimum temperature 25°C.

Habitat: Water.

29. **Micrococcus candicans** Flügge. (Die Mikroorganismen, *2*, 1886, 177; *Staphylococcus candicans* Holland, Jour. Bact., *5*, 1920, 225.)

Spheres: 1.0 to 1.2 microns, occurring singly and in irregular clumps. Gram-positive.

Gelatin colonies: Circular, porcelain white, glistening slightly raised.

Gelatin stab: White, glistening, raised surface growth. No liquefaction.

Agar colonies: Circular, white, smooth, glistening, contoured, entire.

Agar slant: Thick, white, raised, glistening.

Broth: Turbid, with pellicle, becoming clear.

Litmus milk: Slightly acid. No coagulation.

Potato: Scant, thin, yellowish-white streak.

Indol not produced.
Nitrates not reduced.
H_2S not produced.
Non-pathogenic.
Aerobic.
Optimum temperature 25°C.
Habitat: Air, water, milk.

30. **Micrococcus epimetheus** Corbet. (Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 148.)

Spheres, 1.0 micron in diameter, occurring in irregular masses. Non-motile. Gram-positive.
Gelatin stab: No liquefaction.
Agar colonies: White, opaque.
Agar slant: Moderate, gray, moist, raised, glistening.
Broth: Turbid with slight sediment.
Litmus milk: Acid; coagulated; litmus reduced.
Potato
Indol is formed.
Nitrates reduced to nitrite.
Acid and gas in dextrose, lactose, sucrose and arabinose.
Starch is hydrolized.
Ammonia is formed.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Isolated from the latex of *Hevea brasiliensis*.

31. **Micrococcus viscosus** Bergey et al. (*Micrococcus lactis viscosus B*, Conn, Esten and Stocking, Storrs Agr. Exp. Sta., Rept. for 1906, 109; Bergey et al., Manual, 1st ed., 1923, 68.)

Spheres: 0.8 to 0.9 micron, occurring singly. Gram-positive.
Gelatin colonies: Thick, circular, white, smooth.
Gelatin stab: White surface growth. No liquefaction.
Agar slant: White, smooth, spreading.
Broth: Turbid with sediment.
Litmus milk: Becoming slimy.
Potato: Thick, gray, growth. Medium discolored.
Indol not formed.
Nitrates not reduced.
No acid in carbohydrate media.
Aerobic.
Optimum temperature 30°C.
Habitat: Isolated from pasteurized milk.

32. **Micrococcus ureae** Cohn. (Beiträge zur Biologie der Pflanzen, *1*, Heft II, 1872, 158; *Albococcus ureae* Kligler, Jour. Infect. Dis., *12*, 1913, 442; *Staphylococcus ureae*, Holland, Jour. Bact., *5*, 1920, 225.)

Spheres: 0.8 to 1.0 micron, occurring singly, in pairs and occasionally in fours. Never in chains. Gram-positive.

Gelatin colonies: Small, white, translucent, slimy, becoming fissured.

Gelatin stab: Slight, white growth. No liquefaction.

Agar colonies: White, slightly raised.

Agar slant: White, raised, glistening, butyrous.

Broth: Turbid, with viscid sediment.

Litmus milk: Slightly alkaline; litmus slowly reduced.

Potato: Slight, grayish to pale olive growth.

Indol is not formed.

Nitrates not reduced.

Urea is fermented to ammonium carbonate.

Acid produced from dextrose, lactose and sucrose.

Ammonium salts are utilized.

Aerobic.

Optimum temperature 25°C.

Habitat: Isolated from stale urine.

33. **Micrococcus nitrificans** Bergey et al. (Micrococcus 6, Rubentschick, Cent. f. Bakt., II Abt., *72*, 1927, 125; Bergey et al., Manual, 3rd ed., 1930, 88.)

Spheres: 1.1 to 1.3 microns in diameter. Gram-positive.

Gelatin colonies: Circular, grayish-white, raised with radiate border.

Gelatin stab: No liquefaction.

Agar colonies.

Agar slant: Moderate, grayish-white, raised layer.

Broth: Turbid with grayish pellicle.

Litmus milk: Unchanged.

Potato: Yellowish-brown streak.

Indol not formed.

Nitrates are reduced to nitrites.

Urea not attacked.

H_2S not formed.

Ammonia not formed.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Sewage filter beds.

34. **Micrococcus chersonesia** Corbet. (Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 150.)

Spheres, 0.5 to 1.0 micron in size, occurring in irregular groups. Non-motile. Gram-positibe.

Gelatin stab: No liquefaction.

Agar colonies: White, opaque, with translucent area.

Agar slant: Grayish, filiform, flat, dull.

Broth: Turbid with sediment.

Litmus milk: Unchanged.

Potato
Indol is not formed.
Nitrates are not reduced.
No action on carbohydrates.
Ammonia is formed.
Aerobic.
Optimum temperature 30°C.
Habitat: Isolated from the latex of *Hevea brasiliensis.*

35. **Micrococcus halophilus** Bergey et al. (Culture No. 19, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Manual, 3rd ed., 1930, 89.)

Spheres (in media lacking salt, 0.6 to 0.9 micron; in media with 20 per cent NaCl, 1.9 to 2.5 microns), occurring singly, in pairs, and in short chains. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Circular with raised margin and slight convex internal streaks, white, becoming yellowish-white, glistening.

Agar slant: White, glistening, having the appearance of numerous confluent colonies, spreading. On agar containing 10 per cent salt the growth is yellowish. On agar containing 20 per cent salt the growth is slimy.

Broth: Turbid.
Litmus milk: Unchanged.
Potato: White, convex layer.
Indol not formed.
Nitrates not reduced.
Ammonia not formed.
H_2S not formed.
Growth occurs in media with 25 per cent NaCl.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Sea water.

36. **Micrococcus sphaeroides** Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 74.)

Spheres: 0.5 to 0.7 by 1.0 to 1.75 microns, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Circular, whitish or buff, flat, smooth, glistening, erose.
Gelatin stab: No liquefaction.
Agar colonies: Circular, whitish, flat, smooth, glistening, entire.
Agar slant: Filiform, whitish, smooth, glistening, lobate.
Broth: Turbid.
Litmus milk.
Potato.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Attacks phenol and naphthalene.

Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Manure and soil.

37. **Micrococcus piltonensis** Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 74.)

Spheres: 0.7 to 1.0 by 1.5 to 2.0 microns, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Circular, light buff, flat, smooth, resinous, entire.
Gelatin stab: No liquefaction.
Agar colonies: Circular, white, flat, smooth, glistening, erose.
Agar slant: Filiform, whitish-buff streak, smooth, glistening, convex, lacerate.
Broth: Turbid.
Litmus milk.
Potato.
Indol not formed.
Nitrates not reduced.
No acid in carbohydrate media.
Starch not hydrolyzed.
Attacks phenol.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Manure and soil.

Note: Hucker (N.Y. State Agr. Exp. Station, Tech. Bul., 102, 1924) recognizes sixteen aerobic species in genus *Micrococcus* as follows: *Micrococcus luteus*, *M. varians*, *M. flavus*, *M. conglomeratus*, *M. citreus*, *M. albus*, *M. candidus*, *M. epidermidis*, *M. tetragenus*, *M. urea*, *M. freudenreichii*, *M. casei*, *M. aureus*, *M. aurantiacus*, *M. roseus* and *M. cinnebareus*. Later Hucker (N. Y. State Agr. Exp. Station, Tech. Bul. 135, 1928) adds three more species of red cocci, viz. *Micrococcus agilis*, *M. rhodochrous* and *M. roseofulvus*. A long list of synonyms or possible synonyms is given.

38. **Micrococcus buccalis** Bergey et al. (Micrococcus der Mundhöhle, Ozaki, Cent. f. Bakt., I Abt., Orig., *76*, 1915, 118; Manual, 1st ed., 1923, 69.)

Spheres: 0.5 micron in diameter, occurring singly and in pairs and short chains. Gram-positive.

Gelatin stab: No liquefaction.
Dextrose agar colonies: Small, circular, grayish-white, glistening, slightly raised in center.
Dextrose agar streak: Small, grayish, isolated colonies.
Dextrose broth: Turbid, with gas formation. Grayish sediment.
Litmus milk: No change in appearance except gas production.
Potato: Barely visible, grayish-white streak.
Indol not formed.
Nitrates not reduced.
Acid and gas in dextrose and lactose.

Anaerobic.

Optimum temperature 37°C.

Ozaki states that this organism is closely related to *Staphylococcus aerogenes* Schottmüller.

Habitat: Oral cavity.

39. **Micrococcus gingivalis** Bergey et al. (Kleiner Micrococcus, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 83; Manual, 1st ed., 1923, 69.)

Spheres: 0.3 to 0.4 micron in diameter, occurring singly and in pairs. Gram-negative.

Gelatin stab: No liquefaction.

Dextrose agar colonies: Small, grayish-white.

Dextrose agar slant: Thin, transparent streak.

Dextrose broth: Thin, yellowish pellicle. Gas is formed.

Litmus milk: Gas is formed; no coagulation.

Potato: No visible growth.

Indol not formed.

Nitrates not reduced.

Anaerobic.

Optimum temperature 37°C.

Habitat: Oral cavity.

40. **Micrococcus gasogenes** Hall and Howitt. (*Micrococcus gasogenes alcalescens anaerobius* Lewcowicz, Arch. de Méd. Expér., *13*, 1901, 633; Hall and Howitt, Jour. Infect. Dis., *37*, 1925, 112.)

Spheres: 0.3 to 0.4 micron, occurring singly, in pairs, in tetrads, and rarely in chains. Gram-negative.

Growth occurs in ascitic fluid gelatin and in blood gelatin. No liquefaction, or blackening of the medium.

Growth in ascitic fluid agar, and in brain medium; the latter is blackened.

Blood agar colonies: Small, circular, moist, raised, grayish-white. No hemolysis.

Gas is formed in broth containing fresh animal tissue.

Gas is produced in ordinary broth. No fetid odor is produced.

Bromcresol purple milk: Gas is formed.

Potato: Grayish-white streak.

Indol formed in small amounts.

Nitrates not reduced.

Slight amounts of H_2S formed.

Anaerobic.

Growth occurs at 20°C. Optimum temperature 37°C.

Habitat: Isolated from oral cavity.

41. **Micrococcus minimus** (Gioelli) Bergey et al. (*Staphylococcus minimus* Gioelli, Boll. d. R. Accad. Med. di Genova 1907, Abstract in Cent. f. Bakt., I Abt., Ref., *42*, 1908–09, 595; Manual, 1st ed., 1923, 69.)

Spheres: 0.2 to 0.3 micron, occurring singly. Gram-negative.

Gelatin stab: No growth.
Dextrose broth: Turbid.
Litmus milk: No coagulation.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Anaerobic.
Optimum temperature 37°C.
Habitat: Isolated from purulent pelvic cellulitis.

42. **Micrococcus syzygios** Bergey et al. (Syzygiococcus, Herzberg, Cent. f. Bakt., I Abt., Ref., *90*, 1928, 574; *Micrococcus syzygios scarlatinae* Herzberg, Centralbl. f. Bact., I Abt., Orig., *111*, 1929, 373; Manual, 3rd ed., 1930, 92.)

Common name: Syzygiococcus (syzygia = yoked together).

Spheres: 0.4 to 0.5 micron, occurring singly, in pairs and in short chains. Gram-negative.

Gelatin stab: No growth.

Rabbit blood agar colonies: Circular, entire, convex, opalescent. Grows less vigorously on human blood agar. No hemolysis is produced.

Grows poorly on Loeffler's blood serum and not at all on plain, ascitic or glycerol agar. Grows well on dextrose agar.

Indol not formed.

Nitrates reduced to nitrites.

H_2S formed.

Gas in dextrose and lactose broth.

Seventy-two hour cultures in Aldershoff broth, when filtered through Berkefeld V filters, are toxic when injected intradermally, (0.1 cc. of 1:1000 dilution). This effect is inhibited by the serum of persons immune to scarlet fever. The organisms are agglutinated by the same serum.

Microaerophilic (20 to 40 mm. Hg.)

Grows at 20°C. Optimum temperature 37°C.

Habitat: Isolated from throat of scarlet fever patients.

43. **Micrococcus parvulus** (Veillon and Zuber) Bergey et al. (*Staphylo coccus parvulus* Veillon and Zuber, Arch. de Méd. Expér., *10*, 1898, 517 Manual, 3rd ed., 1930, 92.)

Spheres: 0.4 to 0.5 micron, occurring singly, in pairs, and occasionally in short chains. Gram-negative.

Gelatin stab: Liquefied.

Blood agar colonies: Small, circular, entire. Blood shows hemolysis.

Litmus milk: No coagulation.

Indol formed in small amounts.

Nitrates reduced to nitrites.

Blood serum not liquefied.

H_2S formed.

Acid in dextrose and sucrose media. No action on lactose or dextrin.

Anaerobic.
Grows at 20°C. Optimum temperature 37°C.
Habitat: Isolated from oral cavity.

44. **Micrococcus branhamii** Bergey et al. (Gram-negative, anaerobic micrococcus, Branham, Jour. Infect. Dis., *41*, 1927, 203; ibid., *42*, 1928, 230; Manual, 3rd ed., 1930, 92.)

Spheres: 0.5 micron, occurring singly, in pairs and short chains. Gram-negative.

Gelatin stab: Some strains liquefy gelatin. Grows in 10 per cent ascitic fluid gelatin and in 5 per cent blood gelatin.

Blood agar colonies: Small, circular, smooth, raised, glistening, translucent.

Grows in ascitic fluid agar. Feeble growth in meat infusion media.

Good growth in beef heart, chopped meat, and brain mediums. No blackening of media. Trace of gas in beef heart cultures.

Bromthymol blue milk: Acid with precipitation of casein with clear fluid above.

Indol not formed.
Nitrates not reduced.
H_2S formed.
Acid in dextrose broth.
Hemolysis in rabbit blood agar plates.
Anaerobic.
Grows at 20°C. Optimum temperature 37°C.
Habitat: Isolated from nasal washings in influenza.

45. **Micrococcus reniformis** (Cottel) Oliver and Wherry. (*Diplococcus reniformis* Cottel, Compt. rend. Soc. de biol., *52*, 1900, 421; Oliver and Wherry, Jour. Infect. Dis., *28*, 1921, 243.)

Spheres.
Gram-negative.
Gelatin stab: Slight growth.
Ascites-agar: Slight growth.
Agar colonies: No growth.
Agar slant: No growth.
Broth: No growth.
Litmus milk: No growth.
Potato: No growth.
Indol formed.
No acid in carbohydrate media.
Anaerobic.
Optimum temperature 37°C.
Habitat: Vagina; isolated from abscess of urinary tract.

46. **Micrococcus aerogenes** (Schottmüller) Bergey et al. (*Staphylococcus aerogenes* Schottmüller, Cent. f. Bakt., I Abt., Orig., *64*, 1912, 270; Manual, 1st ed., 1923, 70.)

Spheres: 0.6 to 0.8 micron. Gram-variable, usually positive.

Gelatin stab: No growth.

Agar colonies: No growth.

Agar slant: No growth.

Broth: No growth.

Litmus milk: No growth.

Potato: No growth.

Serum-dextrose-agar: Small, yellowish-white colonies, with gas bubbles.

Nitrates not reduced.

Anaerobic.

Optimum temperature 37°C.

Non-pathogenic.

Habitat: Isolated from secretions in puerperal fever.

Note: Prévot (Ann. Sci. Natur., Sér. Bot. et Zool., *15*, 1933, 118) has included the majority of the above listed anaerobic micrococci in a new genus of cocci *Veillonella* under the following names: *Veillonella parvula*, *V. parvula* var. *thomsonii*, *V. parvula* var. *branhamii*, *V. alcalescens* (= *Micrococcus gasogenes* Hall and Howitt), *V. alcalescens* var. *gingivales*, *V. alcalescens* var. *minutissimus*, *V. alcalescens* var. *syzygios*.

Genus VIII. Sarcina *Goodsir, 1842.*

Saprophytes and facultative parasites. Division occurs, under favorable conditions, in three planes, producing regular packets. Usually Gram-positive. Growth on agar abundant, usually with formation of yellow or orange pigment. Dextrose broth slightly acid, lactose broth generally neutral. Gelatin frequently liquefied. Nitrates may or may not be reduced.

The type species is *Sarcina ventriculi* Goodsir.

Key to the species of genus Sarcina.

A. Non-motile forms.
  1. Yellow pigment formed.
    a. Gelatin not liquefied.
      1. *Sarcina ventriculi.*
      2. *Sarcina conjunctivae.*
    aa. Gelatin liquefied.
      b. Milk alkaline; not coagulated.
        c. Nitrates not reduced.
          3. *Sarcina flava.*
      bb. Milk alkaline; coagulated.
        c. Nitrates not reduced.
          4. *Sarcina lutea.*

bbb. Milk unchanged.
c. Nitrates not reduced.
5. *Sarcina subflava.*
2. Orange pigment formed.
a. Milk becoming acid.
b. Nitrates reduced to nitrites.
6. *Sarcina lactea.*
aa. Milk coagulated; peptonized.
7. *Sarcina aurantiaca.*
3. No pigment formed.
a. Gelatin not liquefied.
b. Milk acid; coagulated.
c. Nitrates not reduced.
8. *Sarcina hamaguchii.*
B. Motile forms.
1. Yellow pigment formed.
a. Gelatin not liquefied.
9. *Sarcina citrea.*
10. *Sarcina ureae.*
11. *Sarcina psychrocarterica.*

1. **Sarcina ventriculi** Goodsir. (Edinborough Med. and Surg. Jour., 1842.)

Spheres: 2.5 microns, occurring usually in packets of eight cells, or in larger masses. The cell wall gives the cellulose reaction. Gram-positive.

Gelatin colonies: Small, circular, raised, yellowish.

Gelatin stab: No liquefaction.

Broth: Brownish flaky pellicle on hay infusion with brownish sediment.

Litmus milk.

Potato: Small, dry, orange-yellow colonies.

Indol not formed.

Nitrates not reduced.

Aerobic.

Optimum temperature 30° to 35°C.

Habitat: In stomach contents of man and of animals.

2. **Sarcina conjunctivae** Bergey et al. (*Sarcina citrea conjunctivae* Verderame, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 384; Bergey et al., Manual, 1st ed., 1923, 71.)

Spheres: 0.8 micron in diameter, grouped in packets. Non-motile. Gram-negative.

Gelatin stab: Light yellow surface growth. No liquefaction.

Agar colonies: Small, yellow, entire.

Agar slant: Citron-yellow layer.

Broth: Turbid, with fluocculent sediment.

Litmus milk: Unchanged.

Potato: Thick, citron-yellow layer.

Löffler's blood serum: Slow liquefaction.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, levulose, maltose, sucrose and inulin.
Aerobic.
Optimum temperature 37°C.
Habitat: Conjunctiva.

3. **Sarcina flava** De Bary. (Vorlesungen über Bakterien, 1887, 151.)
Spheres: 1.0 to 2.0 microns, occurring in packets of 16 to 32 cells. Gram-positive.
Gelatin colonies: Small, circular, yellowish.
Gelatin stab: Slowly liquefied.
Agar slant: Yellow streak.
Broth: Slowly becoming turbid with whitish, later yellowish sediment.
Litmus milk: Alkaline, not coagulated.
Potato: Yellow streak.
Indol not produced.
Nitrates not reduced.
Aerobic.
Optimum temperature 30° to 35°C.
Habitat: Air, water, soil.

4. **Sarcina lutea** Schroeter. (Kryptogamenflora von Schlesien, *3*, 1, 1886, 154.)
Spheres: 1.0 to 1.5 microns, showing packets in all media. Gram-positive.
Gelatin colonies: Circular up to 5 mm. in diameter, sulphur-yellow, sinking into the medium.
Gelatin stab: Slow infundibuliform liquefaction.
Agar colonies: Yellow, coarsely granular, circular, raised, moist, glistening, entire margin.
Agar slant: Sulphur to chrome yellow, smooth, soft.
Broth: Clear with abundant yellow sediment.
Litmus milk: Coagulated, becoming alkaline.
Potato: Sulphur to chrome yellow, raised; sometimes limited growth.
Slight indol formation.
Nitrates generally reduced.
No acid from dextrose, lactose or sucrose.
H_2S is formed.
Aerobic.
Optimum temperature 25°C.
Habitat: Air, soil and water, skin surfaces.

5. **Sarcina subflava** Ravenel. (Memoirs Nat. Acad. of Sciences, *8*, 1896, 10.)
Spheres occurring in distinct packets with 8, 16, 32 or more elements on each face. Gram-positive.

Gelatin colonies: Small, yellowish, granular, entire.
Gelatin stab: Whitish surface growth. Stratiform liquefaction.
Agar slant: Pale yellow, smooth, with undulate margin.
Broth: Clear with white flocculi and a thin pellicle.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

6. **Sarcina lactea** Bergey et al. (Manual, 1st ed., 1923, 73.)
Spheres: 0.8 to 0.9 micron; grouped in pairs and packets. Gram-positive.
Gelatin stab: Not liquefied.
Agar colonies: Small, circular, gray, convex, opaque, entire.
Agar slant: Orange, beaded growth.
Broth: Slightly turbid.
Litmus milk: Becoming acid.
Potato: Scant, gray, filiform growth.
Indol not produced.
Nitrates reduced to nitrites.
Acid formed in lactose broth.
Aerobic.
Optimum temperature 30°C.
Habitat: Fresh milk.

7. **Sarcina aurantiaca** Flügge. (Die Mikroorganismen, 1886, 180.)
Spheres developing packets in all media. Gram-positive.
Gelatin colonies: Small, circular, dark yellow, entire margin, sinking into the medium.
Gelatin stab: Infundibuliform liquefaction.
Agar slant: Slightly raised, orange yellow to orange red, soft, smooth.
Broth: Flocculent turbidity, with abundant sediment.
Litmus milk: Coagulation and digestion.
Potato: Raised, yellow-orange, glistening to dull, granular.
Slight indol formation.
Nitrates not reduced.
H_2S is not produced.
Aerobic.
Optimum temperature 30°C.
Habitat: Air and water.

8. **Sarcina hamaguchii** Saito. (Cent. f. Bakt., II Abt., *17*, 1907, 155.)
Spheres, large, grouped in packets. Non-motile. Gram-positive.
Gelatin colonies: Small, circular, white, entire.

Gelatin stab: No liquefaction.
Agar colonies: Small, circular, white, entire.
Agar slant: Thin, transparent, spreading, soft, glistening.
Broth: Clear.
Litmus milk: Acid; soft coagulum formed.
Potato: Barely visible growth.
Indol not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 37°C.
Habitat: Soy bean mash.

9. **Sarcina citrea** (Migula) Bergey et al. (*Micrococcus agilis citreus* Menge, Cent. f. Bakt., *12*, 1892, 52; *Planococcus citreus* Migula, System der Bakterien, 1900, 271; Bergey et al., Manual, 1st ed., 1923, 74.)

Spheres: 0.6 to 0.8 micron, occurring singly, in pairs and in packets. Motile, possessing a single flagellum. Gram-positive.

Gelatin colonies: Small, circular, yellowish, entire, becoming citron-yellow to orange.
Gelatin stab: No liquefaction.
Agar colonies: Small, yellow, convex, entire, smooth, glistening.
Agar slant: Abundant, yellow, plumose, glistening, taking on an orange color with age.
Broth: Turbid.
Potato: Abundant yellow.
Indol not formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 25°C.
Habitat: Air.

10. **Sarcina ureae** (Beijerinck) Bergey et al. (*Planosarcina ureae* Beijerinck, Cent. f. Bakt., II Abt., *7*, 1901, 52; Bergey et al., Manual, 1st ed., 1923, 74.)

Spheres: 0.7 to 1.2 microns, occurring singly, in pairs and in packets. Typical endospores absent, though heat resistant spore-like bodies have been described. Motile, possessing long peritrichous flagella. Gram-positive.

Gelatin colonies: Small, circular, flat, tough, yellowish.
Converts urea into ammonium carbonate.
Aerobic.
Optimum temperature 20°C. Resists heating to 80°C. for 10 minutes.
Habitat: Isolated from urine.

11. **Sarcina psychrocarterica** (Rubentschick) Bergey et al. (*Urosarcina psychrocarterica* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 168; *ibid.*, *66*, 1926, 161; *ibid.*, *67*, 1926, 167; *ibid.*, *68*, 1926, 327; Bergey et al., Manual, 3rd ed., 1930, 95.)

Spheres: 1.2 to 1.5 in diameter, occurring mostly in pairs. Motile. Gram-positive.

Gelatin colonies: Yellow, folded, at times concentrically ringed.

Gelatin stab: No liquefaction.

Agar colonies: Circular, orange-yellow, smooth.

Agar slant: Filiform, yellow, smooth.

Broth: Turbid with thin pellicle.

Litmus milk: Unchanged.

Potato: Filiform, dark yellow, dry.

Indol not formed.

Nitrates reduced to nitrites.

H_2S not formed.

Ammonia not formed.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Sewage slime.

Genus IX. Rhodococcus *Zopf, 1891.*

Saprophytes. Cells in groups or in irregular packets. Usually Gram-positive. Abundant growth with red pigment on surface of culture media. Slight acid from dextrose; none from lactose. Gelatin liquefied by some species. Nitrates usually reduced to nitrites but not to ammonia.

The type species is *Rhodococcus rhodochrous* Zopf.

Key to the species of genus Rhodococcus.

1. Gelatin not liquefied.
   - a. Non-motile.
     1. *Rhodococcus rhodochrous.*
     2. *Rhodococcus cinnebareus.*
   - b. Motile.
     3. *Rhodococcus agilis.*
2. Gelatin liquefied.
   4. *Rhodococcus roseus.*
   5. *Rhodococcus rosaceus.*
   6. *Rhodococcus corallinus.*

1. **Rhodococcus rhodochrous** Zopf. (Berichte der Deutsch. Bot. Gesellschaft, *9*, 1891, 22. *Micrococcus rhodochrous* Migula, System der Bakterien, 1900, 162.)

Spheres: 0.5 to 1.0 micron, occurring singly, in pairs and occasionally in fours. Gram-positive.

Gelatin colonies: Small, circular, glistening, raised, entire, dark, reddish-brown.

Gelatin stab: Dark, carmine-red, dry surface growth. Slight growth in stab. No liquefaction.

Agar slant: Carmine-red streak, becoming cinnebar red in color.

Broth: Thick, rose-red pellicle with red, flocculent sediment.
Litmus milk: Slightly alkaline.
Potato: Carmine-red streak.
Aerobic.
Optimum temperature 25°C.
Habitat: Water.

2. **Rhodococcus cinnebareus** (Flügge) Holland. (*Micrococcus cinnebareus* Flügge, Die Mikroorganismen, 1886, 174; Holland, Jour. Bact., *5*, 1920, 225.)
Spheres: 1.0 micron, occurring singly and in pairs. Gram-positive.
Gelatin colonies: Small, circular, bright red, becoming cinnebar red.
Gelatin stab: Thick, raised, rose to cinnebar red growth on surface. No liquefaction.
Agar slant: A carmine-red streak.
Broth: Turbid.
Litmus milk: Slightly alkaline.
Potato: Slowly developing vermilion red streak
Indol not formed.
Nitrates reduced to nitrites.
Starch not hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Air and water.

3. **Rhodoccus agilis** (Ali-Cohen) Holland. (*Micrococcus agilis* Ali-Cohen, Cent. f. Bakt., *6*, 1889, 36; Holland, Jour. Bact., *5*, 1920, 225.)
Spheres, 1.0 micron, occurring singly, in pairs and in fours. Motile by means of one or two flagella. Gram-positive.
Gelatin colonies: Small, gray, becoming distinctly rose colored.
Gelatin stab: Thin, whitish growth in stab. On surface thick, rose-red glistening growth. Generally no liquefaction.
Agar slant: Glistening, dark rose-red, lobed, much variation in color.
Broth: Slightly turbid, with slight, rose-colored ring and pink sediment.
Litmus milk: Slightly acid, pink sediment.
Potato: Slow growth as small, rose-colored colonies.
Loeffler's blood serum: Pink, spreading, shiny, abundant. Slow liquefaction.
Indol not formed.
Nitrates reduced (trace).
Ammonia formed (trace).
Acid in dextrose, sucrose, inulin, glycerol and mannitol. No acid in raffinose.
Aerobic.
Optimum temperature 25°C.
Habitat: Water, seawater, on sea fish.

4. **Rhodococcus roseus** (Flügge) Winslow and Winslow. (*Micrococcus roseus* Flügge, Die Mikroorganismen, 1886, 183; Winslow and Winslow, Systematic Relationships of the Coccaceae, 1908, 245.)

Spheres: 1.0 to 1.5 microns, occurring singly and in pairs. Gram-positive.

Gelatin colonies: Rose surface growth with slow liquefaction.

Agar slant: Thick, rose red, smooth, glistening streak.

Broth: Slightly turbid with rose-colored sediment.

Litmus milk: Becoming alkaline.

Potato: Raised, rose-red, smooth, glistening.

Aerobic.

Optimum temperature 25°C.

Habitat: Air.

5. **Rhodococcus rosaceus** (Frankland and Frankland) Holland. (*Micrococcus rosaceus* G. and P. Frankland, Trans. Royal Society, London, *178*, B, 1887, 269; Possibly identical with *Micrococcus lactis rosaceus*, Conn, Esten and Stocking, Storrs Agr. Exp. Sta. Rept. 1906; Holland, Jour. Bact., *5*, 1920, 225.)

Spheres: 2.5 microns, occurring singly and in pairs. Gram-positive.

Gelatin colonies: Small, flesh-colored, raised.

Gelatin stab: Smooth, glistening, flesh-colored surface growth. Slight growth in stab. Slow liquefaction.

Agar slant: Luxuriant, light flesh-colored streak.

Broth: Slightly turbid with flesh-colored sediment.

Litmus milk: Acid, with pink sediment.

Potato: Rose-red, glistening, luxuriant.

Indol not formed.

Nitrates not reduced.

Aerobic.

Optimum temperature 25°C.

Habitat: Water and milk.

6. **Rhodococcus corallinus** Levine and Soppeland. (Bul. 77, Engineering Exp. Sta., Iowa State Coll., 1926, 22).

Note: Species that have been regarded as identical are *Micrococcus fulvus* Cohn, Beiträge z. Biol. d. Pflanz., *1* (Heft 3), 1875, 181; *Micrococcus corallinus* Cantani, Cent. f. Bakt., I Abt., *23*, 1898, 311; *Rhodococcus fulvus*, Winslow and Winslow, Systematic Relationships of the Coccaceae, 1908, 245.

Spheres: 0.4 to 0.8 micron in size, occurring singly and in clusters. Gram-positive.

Gelatin colonies.

Gelatin stab: Surface growth pink. Crateriform liquefaction.

Agar colonies: Circular, raised, smooth, entire, amorphous, pink.

Agar slant: Scant, butyrous, filiform, smooth, coral red.

Broth: Slight turbidity; scant granular sediment.

Litmus milk: Unchanged.

Potato: Moderate growth, orange-red.
Indol: Slight after 7 days.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 22°C. No growth at 37°C.
Habitat: Isolated from contaminated plate culture.

FAMILY III. SPIRILLACEAE MIGULA, 1894.

Cells elongate, more or less spirally curved. Cell division always transverse, never longitudinal. Cells non-flexuous, without endospores. As a rule, motile by means of polar flagella, sometimes non-motile. Typically water forms, though some species are intestinal parasites.

Key to the genera of family Spirillaceae.

1. Cells short, bent rods, single or united into spirals.
Genus I. *Vibrio*, p. 109.
2. Cells of varying thickness, and length and pitch of the spiral, forming either long curves or portions of a turn.
Genus II. *Spirillum*, p. 120.

Genus I. Vibrio *Müller, 1773.*

Cells short, bent rods, rigid, single or united into spirals. Motile by means of a single (or rarely, two or three) polar flagellum, which is usually relatively short. Many species liquefy gelatin and are active ammonifiers. Aerobic, facultative anaerobic. No endospores formed. Usually Gram-negative. Water forms; a few are parasites.

The type species is *Vibro comma* (Schroeter).

Key to the species of genus Vibrio.

1. Pathogenic for man or laboratory animals.
   a. Milk not coagulated.
   b. Indol formed.
      1. *Vibrio comma.*
      2. *Vibrio metchnikovii.*
      3. *Vibrio berolinensis.*
   bb. Indol not formed.
      4. *Vibrio strictus.*
   aa. Milk coagulated.
   b. Indol formed.
      5. *Vibrio schuylkiliensis.*
      6. *Vibrio danubicus.*
   bb. Indol not formed.
      7. *Vibrio wolfii.*
      8. *Vibrio sputigenus.*
      9. *Vibrio liquefaciens.*

2. Not pathogenic to man or laboratory animals.
   a. Milk not coagulated.
   b. Indol not formed.
   c. No action on carbohydrates.
   d. Gelatin liquefied.
      10 *Vibrio aquatilis.*
      11. *Vibrio tyrogenus.*
      12. *Vibrio cuneatus.*
   dd. Gelatin not liquefied.
      13. *Vibrio percolans.*
   cc. Acid in dextrose.
   d. Gelatin liquefied.
      14. *Vibrio neocistes.*
   dd. Gelatin not liquefied.
      15. *Vibrio xenopus.*
      16. *Vibrio cyclocites.*
      17. *Vibrio pierantonii.*
      18. *Vibrio andoi.*
   ccc. Acid and gas in dextrose.
   d. Gelatin not liquefied.
      19. *Vibrio leonardii.*
   aa. Milk coagulated.
   b. Indol not formed.
      20. *Vibrio proteus.*
   bb. Indol formed.
      21. *Vibrio piscium.*
   aaa. Action in milk not recorded.
      22. *Vibrio agar-liquefaciens.*

1. **Vibrio comma** (Schroeter) Bergey et al. (Komma-bacillus, Koch, Berliner Klin. Wochenschr., 1884, Nos. 31 and 32; *Spirillum cholerae asiaticae* Zopf, Die Spaltpilze, 1885, 69; *Pacinia cholerae-asiaticae* Trevisan, Atti d. Acad. Fisio-Medico-Statistica in Milano, Ser. 4, *3*, 1885, 84; *Microspira comma* Schroeter, Cohn's Kryptogamen Flora v. Schleisen, *3*, 1, 1886, 168; *Vibrio cholerae* Neisser, Arch. f. Hyg., 19, 1893, 199; *Vibrio cholerae asiaticae* Pfeiffer, Flügge, Die Microorganismen, *2*, 1896, 527; Bergey et al., Manual, 1st ed., 1923, 78.)

Slightly curved rods, 0.4 to 0.6 by 1.5 to 3.0 microns, occurring singly and in spiral chains. Motile, possessing one or two polar flagella. Gram-negative.

Gelatin colonies: Small, yellowish-white.

Gelatin stab: Rapid napiform liquefaction.

Agar colonies: Circular, whitish-brown, moist, glistening, translucent, slightly raised, entire.

Agar slant: Brownish-gray, moist, glistening.

Broth: Slightly turbid, with fragile, wrinkled pellicle and flocculent precipitate.

Litmus milk: Alkaline at the top and slightly acid at bottom; not coagulated; peptonized.

Potato: Dirty-white to yellowish, moist, glistening, spreading.

Blood serum: Slowly liquefied.

Indol is formed.

Nitrates reduced to nitrites.

H_2S is formed.

Acid formed in dextrose, levulose, galactose, maltose, sucrose and mannitol media. Slowly in glycerol. Does not attack lactose, inulin or dulcitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal contents of cholera patients and carriers.

2. **Vibrio metchnikovii** Gamaleia. (Ann. d. l'Inst. Pasteur, *2*, 1888, 482.)

Curved rods, somewhat shorter and thicker than *Vibrio comma*. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Like those of *Vibrio comma*.

Gelatin stab: Rapid, napiform liquefaction.

Agar colonies.

Agar slant: Gray, plumose, moist, glistening.

Broth: Turbid, with strong, gray pellicle.

Litmus milk: Acid, coagulated (eighth day).

Potato: Delicate, brownish growth.

Indol is formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from fowl dead of a choleraic disease.

3. **Vibrio berolinensis** Neisser. (Arch. f. Hyg., *19*, 1893, 200.)

Curved rods, somewhat smaller than *Vibrio comma*. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Small, grayish, slightly granular, fragmented.

Gelatin stab: Slow, napiform liquefaction.

Agar slant: Gray, moist, glistening.

Broth: Turbid, with gray pellicle.

Litmus milk: No coagulation.

Potato: Brownish streak.

Indol is formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from Spree river water.

4. **Vibrio strictus** Kutscher. (Zeitschr. f. Hyg., *19*, 1895, 469.)

Markedly curved rods, of about twice the size of *Vibrio comma*. Motile. Gram-negative.

Gelatin colonies: Small, circular, yellowish, with serrate margin.

Gelatin stab: Slow, napiform to saccate liquefaction.

Agar slant: Growth plumose, moist.

Broth: Turbid, with gray pellicle.

Litmus milk: Not coagulated.

Potato: Thin, barely visible layer.

Blood serum is slowly liquefied.

Indol is not formed.

Nitrates not reduced.

Pathogenic for guinea pigs.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Water.

5. **Vibrio schuylkiliensis** Abbott. (Jour. Exper. Med., *1*, 1896, 424; *Microspira schuylkiliensis* Chester, Manual of Determ. Bact., 1901, 334.)

Rather plump, comma forms, ends rounded to slightly pointed. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Circular, sharply defined, slightly granular, becoming concentric to toruloid

Gelatin stab: Rapid, napiform liquefaction.

Agar slant: Smooth, glistening, opaque.

Broth: Turbid, with thin pellicle.

Litmus milk: Acid; coagulated.

Potato: Slight, dirty, yellowish to brownish streak.

Indol is formed.

Nitrates reduced to nitrites.

Loeffler's blood serum is liquefied.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from water of the Schuylkill and Delaware rivers.

6. **Vibrio danubicus** Heider. (Cent. f. Bakt., *14*, 1893, 341.)

Curved rods like *Vibrio comma*. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Small, circular, transparent, homogeneous.

Gelatin stab: Rapid, napiform liquefaction.

Agar slant: Fairly abundant, grayish, plumose.

Broth: Turbid, with gray pellicle.

Litmus milk: Coagulated.

Potato: Yellowish-brown streak.

Indol is formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 37°C.
Habitat: Isolated from water of the Donau Canal at Vienna.

7. **Vibrio wolfii** (Migula) Bergey et al. (Wolf, Münch. Med. Wochenschr., 1893; *Microspira wolfii* Migula, System der Bakterien, 1900, 1001; Bergey et al., Manual, 1st ed., 1923, 80.)
Curved rods and S-shaped forms. Motile. Gram-negative.
Gelatin colonies: Small, grayish-white, spreading.
Gelatin stab: Infundibuliform liquefaction.
Agar slant: Gray, moist layer.
Broth: Turbid, with gray pellicle.
Litmus milk: Acid; coagulated.
Potato: Yellowish-white layer.
Blood serum: Rapid liquefaction.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from cervical secretions in chronic endometritis.

8. **Vibrio sputigenus** (Migula) Bergey et al. (Brix, Hyg. Rundschau, *4*, 1894, 913; *Microspira sputigena* Migula, System der Bakterien, 1900, 981; Bergey et al., Manual, 1st ed., 1923, 80.)
Slightly curved rods, about the same size and form as *Vibrio comma*, occurring singly, occasionally three or four in a chain. Motile. Possessing a polar flagellum. Gram-negative.
Gelatin colonies: Small, circular, slightly granular, yellowish, becoming brownish.
Gelatin stab: Crateriform liquefaction.
Agar slant: Grayish-white, moist.
Broth: Turbid, no pellicle formed.
Litmus milk: Acid; coagulated.
Potato: Thin, gray layer, spreading.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from sputum.

9. **Vibrio liquefaciens** (Migula) Bergey et al. (Bonhoff, Arch. f. Hyg., *19*, 1893, 248; *Microspira liquefaciens* Migula, System der Bakterien, 1900, 990; Bergey et al., Manual, 1st ed., 1923, 81.)
Comma and S-shaped rods. Motile. Gram-negative.
Gelatin colonies: Circular, with irregular margin, surrounded by a rose-colored zone.
Gelatin stab: Slow, napiform liquefaction.
Agar slant: Smooth, grayish, plumose.

Broth: Turbid, with heavy grayish pellicle.
Litmus milk: Acid; coagulated.
Potato: Moist, brownish layer.
Indol is not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Water.

10. **Vibrio aquatilis** Günther. (Deutsche Med. Wochenschr., 1892, 1124; *Microspira aquatilis* Migula, System der Bakterien, 1900, 993.)

Curved rods, like *Vibrio comma*. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Circular, brownish, finely granular, entire.
Gelatin stab: Crateriform liquefaction.
Agar slant: Moist, grayish, glistening.
Broth: Slightly turbid.
Litmus milk: Not coagulated.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

11. **Vibrio tyrogenus** (Denecke) Bergey et al. (*Spirillum tyrogenum* Denecke, Deutsch. Med. Wochenschr., 1885; *Microspira tyrogena* Migula, System der Bakterien, 1900, 982; Bergey et al., Manual, 1st ed., 1923, 81.)

Curved rods, rather smaller and more slender than *Vibrio comma* often very long, closely wound spirals. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Small, gray, granular, entire.
Gelatin stab: Rapid, saccate liquefaction.
Agar slant: Yellowish-white, plumose, glistening.
Broth: Turbid.
Litmus milk: Not coagulated.
Potato: No growth.
Indol not formed.
Nitrates show slight reduction.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Isolated from cheese.

12. **Vibrio cuneatus** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 92.)

Curved rods: 1.0 by 1.0 to 3.0 microns, the cells tapering at one extremity. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Liquefied.
Gelatin stab: Liquefied.
Agar colonies: Circular to amoeboid, white to buff, flat to convex, smooth, translucent border, entire.
Agar slant: Filiform, whitish, smooth, glistening.
Broth.
Litmus milk.
Potato.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
No acid in carbohydrate media.
Attacks naphthalene.
Aerobic, facultative.
Optimum temperature 30 to 35°C.
Habitat: Soil.

13. **Vibrio percolans** Mudd and Warren. (Jour. of Bact., *8*, 1923, 447.)
Curved rods: 0.3 to 0.4 by 1.5 to 1.8 microns. Actively motile. Gram-negative.
Gelatin stab: No liquefaction.
Agar colonies: Circular, slightly convex, amorphous, entire.
Agar slant: Bluish-white, glistening, streak.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: White, slimy streak.
Indol not formed.
Nitrates not reduced.
Blood serum not liquefied.
Starch not hydrolyzed.
No action on carbohydrates.
Passes through bacterial filters.
Aerobic, facultative.
Optimum temperature 30°C.
Non-pathogenic.
Habitat: Water.

14. **Vibrio neocistes** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 92.)
Curved rods: 0.5 to 1.0 by 1.0 to 4.0 microns. Motile with one to three polar flagella. Gram-negative.
Gelatin colonies: Liquefied.
Gelatin stab: Liquefied. Medium reddened.
Agar colonies: Circular or amoeboid, buff to brownish, convex, smooth, glistening, entire.
Agar slant: Filiform, fluorescent, raised, smooth, glistening, undulate.
Broth: Turbid.

Litmus milk.
Potato.
Indol.
Nitrates not reduced.
Starch not hydrolyzed.
Acid in dextrose media.
Attacks naphthalene.
Aerobic, facultative.
Optimum temperature.
Habitat: Soil.

15. **Vibrio xenopus** Schrire and Greenfield. (Trans. Royal Soc. So. Africa, *17*, 1930, 309.)

Spiral forms, occurring singly and in pairs. Non-motile, Gram-negative.
Gelatin stab: Slow, crateriform liquefaction.
Agar colonies: Small, white, glistening, slimy, entire.
Agar slant: Grayish-white, slimy, entire.
Broth: Turbid with flocculent sediment.
Litmus milk: Unchanged.
Potato: Not reported.
Indol is not formed.
Nitrates are reduced slowly.
Blood serum is peptonized.
Starch is not hydrolyzed.
Acid in dextrose, levulose, maltose, glycerol and sorbitol.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Found in abscess of pectoral muscle of frog.

16. **Vibrio cyclosites** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 92.)

Curved rods: 0.5 to 1.0 by 1.5 to 4.0 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin colonies: Circular, buff to brown, flat, smooth, glistening, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular to irregular, pale buff (later greenish), smooth, entire.

Agar stab: Filiform, greenish buff, raised, smooth, undulate.
Broth: Turbid.
Litmus milk.
Potato.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Acid in dextrose.
Attacks phenol and *m*-cresol.

Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Soil.

17. **Vibrio pierantonii** (Zirpolo) Meissner. (*Bacillus pierantonii* Zirpolo, Boll. Soc. nat. Napoli., *30*, 1918, 206; Meissner, Cent. f. Bakt., II Abt., *67*, 1926, 200.)

Rods: 0.5 by 1.5 microns, with rounded ends. Motile with one to three polar flagella. Gram-negative.

Gelatin colonies: Circular, and irregular lobulate.
Gelatin stab: No liquefaction.
Agar colonies: Circular, light green, smooth, entire.
Glycerin agar slant: Slightly luminous streak.
Broth: Turbid, with pellicle.
Litmus milk.
Potato.
Indol not formed.
Nitrates.
Acid in dextrose and maltose. Some strains also attack lactose, sucrose and mannitol.
Best growth in alkaline media.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from the photogenic organ of the cephalopod *Sepiola intermedia* Naef.

18. **Vibrio andoi** Aoi and Orikura. (Cent. f. Bakt., II Abt., *74*, 1928, 331.)

Curved rods, with more or less tapering ends, c- or s-shaped, 0.5 to 0.8 by 1.5 to 2.5 microns. Motile, with a single polar flagellum. Gram-negative.

Gelatin: No growth.
Agar media: No growth.
Broth: No growth.
Litmus milk: No growth.
Potato: No growth.
Ammonium sulphate agar colonies: Punctiform, circular, concave surrounded with clear zone.
Ammonium sulphate agar slant: Grayish, becoming straw-yellow, sinking into the medium as the agar liquefies.
Cellulose media: No growth.
Starch hydrolyzed.
Dextrose, levulose, galactose, mannose, xylose and "honyak" are fermented.
Xylan is decomposed.
Cellobiose is decomposed.
Aerobic, facultative.

Optimum temperature 25°C.
Habitat: Rotted stable manure.

19. **Vibrio leonardii** Métalnikov and Chorine. (Ann. d. l'Inst. Pasteur, *42*, 1928, 1647.)

Curved rods with rounded ends, 0.5 to 1.0 by 2.0 to 3.0 microns. Motile. Gram-negative.
Gelatin colonies.
Gelatin stab: No liquefaction.
Agar colonies: Small, transparent, circular, having a characteristic odor.
Agar slant.
Blood agar.
Broth: Turbid, with thin pellicle.
Litmus milk: No coagulation, acid, with reduction of litmus.
Potato: Slight, colorless growth.
Indol not formed.
Nitrates reduced to nitrites.
Blood serum not liquefied.
H_2S formed.
Acid and gas in dextrose, levulose, galactose, lactose, sucrose and mannitol.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Highly pathogenic for insects as *Galleria mellonella* L., and *Pyrausta nubialis* Hübn.

20. **Vibrio proteus** Buchner. (Kommabacillus der Cholera nostras, Finkler and Prior, Deutsche Med. Wochenschr., 1884, 632; Buchner, Sitzungsber. d. Gesel. f. Morph. u. Physiol., München, *1*, 1885, 10; *Pacinia finkleri* Trevisan, Atti d. Accad. Fisio.-Medico.-Statistica in Milano, Ser. 4, *3*, 1885, 84; *Microspira finkleri* Schroeter, Cohn's Krytogamen-Flora von Schlesien, *3*, 1, 1886, 168; *Microspira protea* Chester, Manual of Determinative Bacteriology, 1901, 338.)

Names appearing as synonyms: *Spirillum finkleri*, Bergey's Manual, 2nd ed., 1925, 87; *Vibrio finkleri ibid.*

Curved rods: 0.4 to 0.6 by 2.4 microns, often pointed at both ends. Motile, possessing a polar flagellum. Gram-negative.
Gelatin colonies: Small, gray, circular, granular, entire.
Gelatin stab: Rapid, saccate liquefaction.
Agar slant: Dirty, grayish, plumose.
Broth: Turbid, with fetid odor.
Litmus milk: Slightly acid; coagulated; peptonized.
Potato: Grayish, slimy layer.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Intestinal contents in cholera nostras and cholera infantum.

21. **Vibrio piscium** David. (Cent. f. Bakt., I Abt., Orig., *102*, 1927, 46.)

Curved rods, 0.3 to 0.5 by 2.0 microns. Motile with a single polar flagellum. Gram-negative.

Gelatin colonies: Circular, granular, opaque.

Gelatin stab: Napiform liquefaction.

Agar colonies: Yellowish, circular, smooth, entire, iridescent.

Agar slant: Light yellow, transparent streak.

Broth: Slight turbidity, with thin pellicle.

Litmus milk: Soft coagulum. Peptonized, alkaline.

Potato: Brownish-red streak

Indol is formed.

Nitrates not reduced.

H_2S formed.

No action in sugar media.

Aerobic, facultative.

Optimum temperature 18° to 20°C.

Habitat: Causes epidemic infection in fish. Pathogenic for frogs.

22. **Vibrio agar-liquefaciens** (Gray and Chalmers) *comb. nov.* (*Microspira agar-liquefaciens* Gray and Chalmers, Ann. Appl. Biol., *11*, 1924, 325.)

Short curved rods, usually c-shaped, with occasional s-shaped and coccoid forms. Cells 2.0 microns long by 0.5 to 0.7 microns broad; 3.0 to 5.0 microns long in division stages. Coccoid forms stained, 0.5 to 0.7 microns long. Motile with a single polar flagellum. Gram stain not reported.

Gelatin stab: Very slight surface growth after one month; the streak then shows a beaded line. No liquefaction.

Agar colonies: Surface colonies appear as a whitish growth in a depression, surrounded by a white ring. The colony is later surrounded by a ring of liquid agar. Deep colonies show a clear area and may be irregular, oval or angular.

Agar slant: A deep groove is cut along the inoculation streak, whitish growth along sides. The gel is later much weakened.

Broth: Liquid slightly clouded.

Acid from glucose, lactose, and maltose. No acid from sucrose or glycerine.

Utilizes ammonia salts as a source of nitrogen.

Decomposes cellulose, and agar. The presence of one per cent glucose prevents the liquefaction of agar.

Nitrates reduced to nitrites.

Starch is hydrolized.

Aerobic.

Temperature relationships: Optimum 25°C., will grow at 16° but not at 34°C.

Habitat: Soil.

Genus II. Spirillum *Ehrenberg, 1830.*

Cells rigid, rods of varying thickness, length, and pitch of spiral, forming either long screws or portions of a turn. Usually motile by means of a tuft of polar flagella (5 to 20) which are mostly half circular, rarely curled. The flagella occur at one or both poles; the number varies greatly and is difficult to determine. Found in water and putrid infusions.

The type species is *Spirillum undula* (Müller) Ehrenberg.

Key to the species of genus Spirillum.

1. Gelatin not liquefied.
   - a. Yellow pigment formed.
     - 1. *Spirillum undula.*
   - aa. Red pigment formed.
     - 2. *Spirillum rubrum.*
2. Gelatin liquefied.
   - a. Without pigment formation.
     - 3. *Spirillum volutans.*
     - 4. *Spirillum virginianum.*
   - aa. Greenish-yellow pigment is formed.
     - 5. *Spirillum serpens.*

1. **Spirillum undula** (Müller) Ehrenberg. (*Vibrio undula* Müller, Animalcula infusoria et marina, 1786; Ehrenberg, Infusionstierchen, 1838.)

Stout threads, 1.2 to 1.5 by 8 microns, with one-half to three turns. The wave lengths are 4 to 5 microns. Bundles of three to nine flagella at each pole. Gram-positive.

Gelatin colonies: The surface colonies are circular, granular, greenish-yellow, entire.

Gelatin stab: Thick, white, rugose surface growth. No liquefaction.

Broth: Turbid.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Putrid and stagnant water.

2. **Spirillum rubrum** Esmarch. (Cent. f. Bakt., *1*, 1887, 230.)

Sharp spirals, 0.6 to 0.8 by 1.0 to 3.2 microns, with one to three twists, on solid media; longer forms in liquid media. Motile, possessing bundles of flagella at both poles. Glistening spots are seen in the organism. Gram-positive.

Gelatin colonies: Surface colonies, small, colorless. Deep colonies pale red to wine red in color.

Gelatin stab: Colorless growth on surface. Red growth in stab. No liquefaction.

Agar slant: Moist, glistening, grayish-white, limited, taking on a wine red color in the thicker portion of the layer.

Broth: Slightly turbid, with reddish sediment.

Litmus milk: Slightly alkaline.

Potato: Small, deep-red, isolated colonies.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Water.

3. **Spirillum volutans** Ehrenberg. (Die Infusionstierchen als Volkommene Organismen, 1838.)

Spirals 2 to 3 by 30 to 50 microns, with slightly attenuated ends. Motile, possessing a bundle of three to eight flagella at each pole. Dark granules of volutin in the cytoplasm. Gram-positive.

Gelatin colonies: Gray, smooth, glistening, entire.

Gelatin stab: Porcelain-white, crumpled surface growth. Slight growth in stab. Slow liquefaction.

Broth: Turbid.

Litmus milk: Unchanged to slightly alkaline.

Potato: Dry brown streak.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Stagnant water.

4. **Spirillum virginianum** Dimitroff. (Jour. of Bact., *12*, 1926, 19.)

Spirals consisting of ½ to 3 complete turns in young cultures, older cultures showing 7 turns. 0.3 to 0.9 by 3 to 11 microns. Motile with a single polar flagellum. Gram-positive.

Gelatin colonies: Gray, smooth, glistening, entire.

Gelatin stab: Porcelain-white surface growth, slight growth in stab. Slow liquefaction.

Agar colonies: (Not cultivated.)

Agar slant: (Not cultivated).

Broth: Turbid.

Litmus milk: Unchanged to slightly alkaline.

Potato: Dark brown streak.

Indol not formed.

Nitrates not reduced.

No action on carbohydrates.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Water.

5. **Spirillum serpens** (Müller) Winter. (*Vibrio serpens* Müller, Animalcula infusoria et marina, 1786; Rabenhorst's Kryptogamen-Flora, Winter, *1*, Die Pilze, 1884, 63.)

Long, curved rods with two to three wave-like undulations, 0.8 to 1.0 by 10 to 30 microns. Motile, possessing bundles of flagella at both poles. Gram-positive

Gelatin colonies: Greenish-yellow to brownish, granular, entire.

Gelatin stab: Greenish-yellow surface growth. Slow liquefaction.

Agar colonies: Deep colonies yellow-green.

Agar slant: Grayish, with yellowish center, granular, entire.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Thick, whitish, moist.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Stagnant water.

FAMILY IV. BACTERIACEAE COHN, 1872.

Rod-shaped cells without endospores. Motile or non-motile. Metabolism complex, amino-acids being utilized, and generally carbohydrates.

Key to the tribes of the family **Bacteriaceae.**

1. Saprophytes or parasitic for plants. Optimum temperature 30°C. or less.
    - a. Gram-negative.
        - b. Pigment produced.
            - c. Grow well on ordinary media.
                - Tribe I. *Chromobacterieae*, p. 123
            - cc. Grow poorly on ordinary media.
                - Tribe II. *Protaminobacterieae*, p. 190
        - bb. No pigment produced, or only a pale yellow pigment.
            - c. Cellulose digested.
                - Tribe III. *Cellulomonadeae*, p. 193
            - cc. Cellulose not digested.
                - d. Saprophytes.
                    - Tribe IV. *Achromobacterieae*, p. 209
                - dd. Plant parasites.
                    - Tribe V. *Erwineae*, p. 248
    - aa. Gram-positive.
        - e. Ferment carbohydrates.
            - f. Microaerophilic.
                - Tribe VI. *Lactobacilleae*, p. 300

ff. Aerobic.

Tribe VII. *Propionibacterieae*, p. 321

ee. Do not ferment carbohydrates.

Tribe VIII. *Kurthieae*, p. 327

2. Parasitic for animals. Optimum temperature 37.5°C.

a. Aerobic.

b. Show bipolar staining.

Tribe IX. *Pasteurelleae*, p. 329

bb. Do not show bipolar staining.

c. Encapsulated.

Tribe X. *Klebsielleae*, p. 333

cc. Not encapsulated.

d. Require blood medium.

Tribe XI. *Hemophileae*, p. 337

dd. Do not require blood medium.

Tribe XII. *Bacterieae*, p. 342

aa. Anaerobic.

Tribe XIII. *Bacteroideae*, p. 404

TRIBE I. CHROMOBACTERIEAE COMMITTEE S. A. B., 1920.

Water and soil bacteria producing a red, yellow, violet or blue-green pigment. Grow well on artificial culture media.

Key to the genera of tribe Chromobacterieae.

1. Small, aerobic rods, producing a red or pink pigment on agar or gelatin.
   Genus I. *Serratia*, p. 123
2. Small, aerobic rods, producing a yellow pigment on gelatin or agar.
   Genus II. *Flavobacterium*, p. 135
3. Small, aerobic rods, producing a violet pigment on solid media.
   Genus III. *Chromobacterium*, p. 169
4. Small, aerobic rods, producing a green or blue-green pigment.
   Genus IV. *Pseudomonas*, p. 174

Genus I. **Serratia** *Bizio, 1823.*

The genus is divided into *Serratia* proper, a group of species closely related to *Aerobacter*, and a miscellaneous group of red and pink chromogens that are placed, for convenience, in an appendix to the genus until comparative studies have shown their true systematic relationships.

Serratia proper (Breed and Breed, Cent. f. Bakt., II Abt., *71*, 1927, 435; Pederson and Breed, Jour. Bact., *16*, 1928, 163) includes small, aerobic, rapidly liquefying, nitrate reducing, Gram-negative, peritrichous rods which produce the characteristic pigment prodigiosin. This varies in shade from a brilliant orange red, with or without metallic luster, in fresh cultures and alkaline media, to dark magenta red in old cultures and acid media. White to rose red strains that lack brilliant colors are com-

mon. Coagulate and digest milk. Liquefy blood serum. Produce CO_2 and frequently H_2 from dextrose and other sugars; also acetic, formic, succinic and lactic acids, acetyl methyl carbinol and 2,3 butylene glycol.

Other small aerobic and facultative anaerobic rods producing a red or pink pigment are temporarily included in this genus as Part II. Usually Gram-positive or variable. Usually nonliquefiers. Rarely liquefy gelatin rapidly. Nitrate reduction variable. Motile or non-motile.

The type species is *Serratia marcescens* Bizio.

Key to the species of genus **Serratia.**

I. Serratia proper. Rods which liquefy gelatin rapidly, normally producing a red pigment prodigiosin.
 a. Produce not more than a bubble of gas from dextrose in Smith fermentation tubes.
 b. Inconspicuous pellicle, if any, on plain gelatin.
 1. *Serratia marcescens.*
 2. *Serratia pyoseptica.*
 3. *Serratia fuchsina.*
 4. *Serratia mineacea.*
 5. *Serratia amylorubra.*
 6. *Serratia rutilis.*
 7. *Serratia kielensis.*
 8. *Serratia rutilescens.*
 bb. Brilliant orange red pellicle on plain gelatin.
 9. *Serratia indica.*
 10. *Serratia miquelii.*
 aa. Produce enough H_2 with the CO_2 from dextrose to show gas in Smith fermentation tubes.
 11. *Serratia plymouthensis.*

II. Other rods producing a red or pink pigment.
 1. Motile rods. Location of flagella not stated.
 a. Gelatin liquefied.
 b. Nitrates not reduced.
 12. *Serratia rubida.*
 aa. Gelatin not liquefied.
 b. No gas in carbohydrate media.
 c. Milk acid.
 13. *Serratia lactorubefaciens*
 cc. Milk alkaline.
 d. Nitrates reduced.
 14. *Serratia rubefaciens.*
 dd. Nitrates not reduced.
 15. *Serratia rubra.*
 2. Motile rods. Flagella polar.
 a. Gelatin not liquefied.

b. Nitrates reduced.

16. *Serratia corallina.*

bb. Nitrates not reduced.

17. *Serratia salinaria.*

3. Non-motile rods.
a. Gelatin liquefied.
b. No gas in carbohydrate media.
c. Milk acid, coagulated, becoming alkaline.
d. Nitrates reduced.

18. *Serratia lactica.*
19. *Serratia subrufa.*

cc. Milk acid, becoming alkaline.
d. Nitrates reduced.

20. *Serratia latericea.*

dd. Nitrates not reduced.

21. *Serratia rubrica.*
22. *Serratia rufa.*

aa. Gelatin not liquefied.
b. Gas in carbohydrate media.

23. *Serratia havaniensis.*

bb. No gas in carbohydrate media.
c. Milk alkaline.
d. Nitrates reduced.

24. *Serratia rosea.*

cc. Milk unchanged.
d. Nitrates not reduced.

25. *Serratia rubropertincta.*

dd. Nitrates reduced.

26. *Serratia roseo-alba.*
27. *Serratia bruntzii.*

1. **Serratia marcescens** Bizio. (Polenta porporina, Biblioteca italiana, *30*, 1823, 288.)

Synonyms: *Zaogalactina imetrofa* Sette, Memoria storico-naturale sull' arrossimento straordinario di alcune sostanze alimentose. Venezia, 8°, 1824, 51; *Protococcus imetrophus* Meneghini, 1838, see Trevisan, Rend. R. Inst. Lomb. di Sci. e Let. Ser. 2, *20*, 1887, 797; *Monas prodigiosa* Ehrenberg, Bericht ü. d. z. Bekanntmachung geeigneten Verhandlungen d. Kgl. preuss. Acad d. Wissenschaften, 1849, 354; *Palmella prodigiosa* Montague, Bul. Soc. nat. et cent. d. agric. Paris, Sér. 2, *7*, 1853, 527; *Micraloa prodigiosa* Zanardini, see Trevisan, 1887, loc. cit., 799; *Bacteridium prodigiosum* Schroeter, Cohn's Beiträge z. Biol. d. Pfanzen, Bd. 1, Heft 2, 1872, 109; *Micrococcus prodigiosus* Cohn, ibid., 127; *Bacillus prodigiosus* Flügge, Die Microorganismen, 1886, 284; *Bacillus imetrophus* Trevisan, loc. cit. 797; *Bacillus marcescens* De Toni and Trevisan, Saccardo's Sylloge Fungorum, *8*, 923; *Bacterium prodigiosum* Lehmann and Neumann, Atlas u.

Grundriss d. Bakteriologie, 1896, 259; *Liquidobacterium prodigiosum* Orla-Jensen, Cent. f. Bakt., II Abt. *22*, 1909, 339; *Erythrobacillus prodigiosus* Winslow et al., Jour. Bact., *5*, 1920, 209; *Dicrobactrum prodigiosum* Enderlein, Bakterien Cyclogenie, 1925, 279; *Chromobacterium prodigiosum* Topley and Wilson, Principles of Bacteriology, *1*, 1931, 402.

Largely taken from Breed and Breed, Jour. Bact., *9*, 1924, 545.

Coccobacteria: 0.5 by 0.5 to 1.0 micron, occurring singly and occasionally in chains of 5 or 6 elements. Motile, with four peritrichous flagella. Gram-negative.

Gelatin colonies: Thin, slightly granular, gray becoming red, circular, with slightly undulate margin. Liquefies the medium rather quickly.

Gelatin stab: Infundibuliform liquefaction. Sediment in liquefied medium usually red on top, white in the depth.

Agar colonies: Circular, thin, granular, gray, becoming red.

Agar slant: White, smooth, moist layer, taking on an orange red to fuchsin color in three or four days, sometimes with metallic luster.

Broth: Turbid, may form a red ring at surface or slight pellicle, and gray sediment.

Litmus milk: Acid reaction with soft coagulum. A red surface growth develops. Little or no digestion takes place.

Potato: At first, a white line appears, which rapidly turns red. The growth is luxuriant and frequently shows a metallic luster.

Produces acetic, formic, succinic and levolactic acid, ethyl alcohol, acetyl methyl carbinol, 2,3 butylene glycol, CO_2 and a trace of H_2 from dextrose.

Will not grow in distilled water containing urea, potassium chloride and dextrose.

Indol not produced.

Nitrates reduced to nitrites.

Odor of trimethylamine is produced.

Aerobic, facultative.

Optimum temperature 25° to 30°C. No growth at 37°C.

Habitat: Water, soil, milk, foods.

2. **Serratia pyoseptica** (Fortineau) Bergey et al. (*Erythrobacillus pyosepticus* Fortineau, Thesis, Faculty of Medicine, Paris, 1904; abstract in Bull. d. l'Inst. Pasteur, *3*, 1905, 13; Bergey et al., Manual, 1st ed., 1923, 89.)

No constant differences have been detected between *Seratia marcescens* and authentic cultures of *Serratia pyoseptica*.

Isolated from shirt of hospital patient. Pathogenic for guinea-pigs and birds. Forms a soluble toxin.

3. **Serratia fuchsina** (Boekhout and DeVries) Bergey et al. (*Bacillus fuchsinus* Boekhout and DeVries, Cent. f. Bakt. II Abt., *4*, 1898, 497; Bergey et al., Manual, 1st ed., 1923, 91.)

The original culture of this species appears to have been a heavy pigmented strain of *Serratia marcescens* showing metallic luster. No authentic cultures are available.

Isolated from water.

4. **Serratia mineacea** (Zimmermann) Bergey et al. (*Bacillus mineaceus* Zimmermann, Die Bakterien unserer Trink-und Nutzwässer, Chemnitz, I, and II, 1890; Bergey et al., Manual, 1st ed., 1923, 90.)

The original of this species appears to have been a heavily pigmented strain of *Serratia marcescens* or *Serratia plymouthensis*, showing metallic luster. No cultures appear to be available.

Isolated from water.

5. **Serratia amylorubra** (Hefferan) Bergey et al. (*Bacillus amyloruber* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; Bergey et al., Manual, 1st ed., 1923, 90.)

The characters given by the author of this species are not different from those of *Serratia marcescens*. The growth on starch-peptone media is not specific. No cultures of the original appear to be available.

Isolated from Mississippi river, also from buttermilk.

6. **Serratia rutilis** (Hefferan) Bergey et al. (*Bacillus rutilis* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; Bergey et al., 1st ed., 1923, 94.

The original of this species appears to have been a heavily pigmented strain of *Serratia marcescens* or of *Serratia plymouthensis*. No characters are given that distinguish it from these species and no cultures appear to be available.

Isolated from Illinois river water.

7. **Serratia kielensis** (Lehmann and Neumann) Bergey et al. (Bacterium h, Breunig, Dissertation, Kiel, 1888; *Bacterium kiliense* Lehmann and Neumann, Atlas u. Grundriss der Bakteriologie, 1896, 263; *Bacillus ruber balticus* Kruse in Flügge, Die Mikroorganismen, *2*, 1896, 303; Bergey et al., Manual, 1st ed., 1923, 90.)

The original description of this organism is too incomplete to make it possible to distinguish it from *Serratia marcescens*. The cultures of this organism that are available at present under this name in culture collections or that have previously been identified as *Serratia kielinsis* are of three different types.

Isolated from Kiel water.

8. **Serratia rutilescens** (Hefferan) Bergey et al. (*Bacillus rutilescens*, Cent. f. Bakt., II Abt., *11*, 1903, 313; Bergey et al., Manual, 1st ed., 1923, 91.)

The characters given by the author of this species do not distinguish it from strains of *Serratia marcescens* that have nearly lost their power of pigment production except that it is reported to grow rapidly at 37°C. No authentic cultures appear to be available.

Isolated from Mississippi river water.

9. **Serratia indica** (Eisenberg) Bergey et al. (*Bacillus indicus* Eisenberg, Bakteriologische Diagnostik, 1886, 1; *Micrococcus indicus* Koch, Berichte ueber die Reise zur Erforschung der Cholera, 1887; Breed and Breed, Jour. of Bact., *11*, 1926, 76; Bergey et al., Manual, 1st ed., 1923, 88.)

Small rods: 0.5 by 1.0 to 1.5 microns. Motile with four peritrichous flagella Gram-negative.

Gelation colonies: Resemble those of *Serratia marcescens*.

Gelatin stab: Liquefied rather quickly. Brilliant orange red pellicle on plain gelatin.

Agar colonies: Pink, with slightly serrate margin, spreading, with green iridescens.

Agar slant: Luxuriant, dirty-white layer. Pigment produced best in alkaline media.

Broth: Turbid, with white sediment.

Litmus milk: Acid and coagulated. Digestion complete in 10 days.

Potato: Luxuriant growth with or without pigment formation.

Produces same products, except H_2, from dextrose as does *Serratia marcescens*.

Indol is not produced.

Nitrates reduced to nitrites.

Growth with pigment production in distilled water containing urea, potassium chloride and dextrose.

Blood serum liquefied.

Odor of methylamine.

Aerobic, facultative.

Optimum temperature 25° to 35°C. No growth at 37°C.

Isolated from alimentary tract of an ape, also from milk can.

10. **Serratia miquelii**, Bergey et al. (Named *Bacillus ruber* by Mique and described in a letter to Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 402; Bergey et al., Manual, 1st ed., 1923, 95.)

This non-gelatin liquefying strain of *Serratia* has been described by Miquel and by Hefferan as being in all other respects like *Serratia marcescens*. Cultures labeled with the specific name *ruber* are still available in American culture collections. These are quite probably substrains of Miquel's *Bacillus ruber* that were studied by Hefferan. These cultures now liquefy gelatin with an orange pellicle and show other characteristics like those of *Serratia indica*. This is the only non-liquefying strain of these organisms that has ever been reported.

Isolated from water.

11. **Serratia plymouthensis** (Migula) Bergey et al. (Roter Bacillus von Plymouth, Fisher, Zeitschr. f. Hyg., *2*, 1887, 74; *Bacterium plymuthicum* Lehmann and Neumann, Atlas u. Grundriss d. Bakteriologie, 1896, 246; *Bacillus plymouthensis* Migula, System der Bakterien, 1900, 849; Bergey et al., Manual, 1st ed., 1923, 88.)

Distinct rods: 0.6 by 1.5 to 2.0 microns, with rounded ends, occurring singly and in short chains. Motile by means of peritrichous flagella. Gram-negative.

Gelatin colonies: Like *Serratia marcescens.* Original culture slimy.

Gelatin stab: Crateriform liquefaction. Liquefaction as in *Serratia marcescens.*

Agar colonies: Like slimy varieties of *Serratia marcescens.*

Agar slant: Sometimes show metallic luster. Pigment as in *Serratia marcescens.*

Broth: Like *Serratia marcescens.*

Litmus milk: Acid and coagulated.

Potato: Growth violet pink, with or without metallic luster.

Gas in dextrose, lactose and sucrose, 70–80 per cent of it CO_2. Remainder is H_2. Gas is also produced in asparagin solution.

Strong fecal odor produced.

Blood serum liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Isolated from water supply of Plymouth, England.

12. **Serratia rubida** (Eisenberg) Levine and Soppeland. (*Bacillus rubidus* Eisenberg, Bakteriologische Diagnostik, Hamburg and Leipzig, 1891, 88; Levine and Soppeland, Bul. 77, Engineering Exp. Sta., Iowa State Coll., 1926, 53.)

Rods: 0.4 to 0.6 by 1.0 to 3.0 microns, occurring singly and in pairs. Motile. Gram-negative.

Gelatin colonies: Circular, finely granular, entire, with reddish center.

Gelatin stab: Napiform liquefaction.

Agar colonies: Small, flat, smooth, amorphous, entire, pink.

Agar slant: Pink to brownish-red streak, glistening, butyrous.

Broth: Slightly turbid.

Litmus milk: Unchanged.

Potato: Scant, pink streak, becoming brownish-red.

Indol not formed.

Nitrates not reduced.

Starch hydrolyzed.

Blood serum liquefied.

No action on sugar media.

Aerobic, facultative.

Optimum temperature 22°C.

Habitat: Water and buttermilk.

13. **Serratia lactorubefaciens** (Gruber) Bergey et al. (*Bacillus lactorubefaciens* Gruber, Cent. f. Bakt., II Abt., *8*, 1902, 457; Bergey et al., Manual, 1st ed., 1923, 92.)

Small rods: 0.4 to 0.6 by 3.5 microns, occurring singly and in pairs Motile by means of peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish-white, smooth, glistening, spreading.

Gelatin stab: At times arborescent; the medium tinged with red. No liquefaction.

Agar colonies: Circular, lobed, grayish, contoured.

Agar slant: White, spreading growth.

Broth: Turbid, with grayish pellicle and slimy sediment.

Litmus milk: Becomes rose red, slimy, slightly acid, without coagulation.

Potato: White, spreading growth.

No gas in carbohydrate media.

Indol not produced.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Milk.

14. **Serratia rubefaciens** (Zimmermann) Bergey et al. (*Bacillus rubefaciens* Zimmermann, Die Bakterien unserer Trink- und Nutzwässer, Chemnitz, 1890, 26; Bergey et al., Manual, 1st ed., 1923, 92.)

Rod, 1.0 to 1.6 microns in length, occurring singly and in pairs. Actively motile. Gram-negative.

Gelatin colonies: Minute, white.

Gelatin stab: Surface growth yellowish, the medium taking on a red tinge. No liquefaction.

Agar colonies: Small, white with erose margin.

Agar slant: White, smooth, glistening, somewhat luxuriant, the medium taking on a wine red color.

Broth: Turbid with white pellicle, the medium slowly assuming a reddish tinge.

Litmus milk: Acid, with slow coagulation and reduction of the litmus. Becoming alkaline.

Potato: A heavy, white, creamy layer, which later becomes yellowish-brown.

No gas in carbohydrate media.

Indol not produced.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 25°C. No growth at 37°C.

Habitat: Water.

15. **Serratia rubra** (Zimmermann) Bergey et al. (*Bacillus ruber* Zimmermann, Die Bakterien unser Trink- und Nutzwässer, Chemnitz, 1890, 24; Bergey et al., Manual, 1st ed., 1923, 92.)

Rod, small, actively motile. Gram-negative.

Gelatin stab: No liquefaction.

Broth: A pink pellicle is formed, with floating particles in the fluid.

Litmus milk: Alkaline.

Potato: Slight, red growth develops slowly.

No gas in dextrose.
Indol is not produced.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25°C. No growth at 37°C.
Habitat: Water.

16. **Serratia corallina** Bergey et al. (*Bacillus mycoides corallinus* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; Bergey et al., Manual, 1st ed., 1923, 93.)

Rods, small, slender, 1.2 to 2.0 microns in length, occurring singly and in pairs. Actively motile by means of a polar flagellum. Gram-negative.
Gelatin colonies: Minute, becoming pink, smooth, raised.
Gelatin stab: Slow growth. Raised, smooth, glistening, pink surface growth. Fine, feathery growth in stab. No liquefaction.
Agar colonies: Minute, with filamentous margin.
Agar slant: Smooth, moist, salmon pink.
Broth: Turbid, with pink flakes on surface.
Litmus milk: Alkaline, with red surface
Potato: Like agar slant.
Nitrates reduced to nitrites.
Indol not formed.
No gas in carbohydrate media.
Aerobic, facultative.
Optimum temperature 30° to 25°C.
Habitat: Isolated from Mississippi river water.

17. **Serratia salinaria** (Harrison and Kennedy) Bergey et al. (*Pseudomonas salinaria* Harrison and Kennedy, Trans. Royal Soc. of Canada, *16*, 1922, 121; Bergey et al., Manual, 1st ed., 1923, 93.)

Occurs as spheres and rods, 2.0 to 3.0 microns in diameter, 1.0 to 1.6 by 3.0 to 15.0 microns, occurring singly, as ovoid, amoeboid, clavate, cuneate, truncate, spindle, club, pear-shape, and in irregular forms. Motile, having a flagellum at each pole. Gram-negative.
Does not grow on ordinary culture media. Grows well on salted fish.
Codfish agar (16 % to 30 % salt): Growth slow, smooth, raised, coarsely granular, entire, pale pink to transparent cherry-red.
No acid in carbohydrate media.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 42°C.
Habitat: Produces red spots on dried codfish and causes "rusty" herring. In sea salt, and sea water.

18. **Serratia lactica** Bergey et al. (*Bacillus lactis erythrogenes* Hueppe. See Grotenfeldt, Fortschrit. der Med., 7, 1889, 41; Bergey et al., Manual, 1st ed., 1923, 93.)

Rod, 0.4 to 0.5 by 1.0 to 1.4 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, circular, grayish-white, later yellow, sinking into the medium. Medium rose color.

Gelatin stab: Slow liquefaction at the surface, the liquid becoming red, with yellow sediment. The solid portion assumes a weak rose color.

Agar slant: Moist, fairly luxuriant, yellow growth, the medium assuming a rose to wine color.

Broth: Turbid, yellow.

Litmus milk: Acid. Slow coagulation, having a clear fluid which becomes blood red in color. The reaction becomes alkaline.

Potato: Yellow, with sometimes a slight pink tinge, the medium becoming dark.

No gas in carbohydrate media.

Sweet odor.

Grows and forms pigment at 37°C.

Indol is not formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Milk and water.

19. **Serratia subrufa** (Burri and Staub) Bergey et al. (*Bacterium subrufum* Burri and Staub, Landwirtsch. Jahrbücher d. Schweiz, *40*, 1926, 1006; Bergey et al., Manual, 3rd ed., 1930, 123.)

This organism is stated to be closely related to and possibly identical with *B. lactis erythrogenes*.

20. **Serratia latericea** (Adametz) Bergey et al. (*Bacillus latericeus* Adametz, Die Bakterien der Trink- und Nutzwässer, Mitteil. der oestrr. Versuchsanst. f. Brauerei u. Malzerei in Wien, 1888, 50; Bergey et al., Manual, 1st ed., 1923, 94.)

Rod, 0.5 to 0.7 by 1.0 to 1.3 microns. Non-motile. Gram-negative.

Gelatin colonies: Small, white, granular with slightly irregular margin.

Gelatin stab: A thin, dry, spreading cream-pink surface growth. No liquefaction.

Agar colonies: Dry, glistening, whitish with irregular margin.

Agar slant: Brick-red, smooth, glistening, butyrous.

Broth: Thick pellicle; fluid clear.

Litmus milk: Alkaline.

Potato: Brick-red streak.

No gas in carbohydrate media.

Indol is not produced.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Water.

21. **Serratia rubrica** (Hefferan) Bergey et al. (*Bacillus rubricus* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; Bergey et al., Manual, 1st ed., 1923, 94.)

Rod: 0.7 to 0.9 by 1.0 to 4.0 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, circular, yellow-orange, deepening to red.

Gelatin stab: Slow liquefaction. Old cultures lose this property.

Agar colonies: Circular, raised, entire.

Agar slant: Moist, spreading, white to pink, gradually deepening in color.

Broth: Turbid, with viscid sediment.

Litmus milk: Alkaline.

Potato: Slight growth, bright pink, turning coral red.

No acid or gas in carbohydrate media.

Indol not produced.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25° to 30°C. No growth at 37°C.

Habitat: Isolated from Mississippi river water, also from buttermilk

22. **Serratia rufa** (Hefferan) Bergey et al. (*Bacillus rufus* Hefferan, Cent. f. Bakt., II Abt., *11*, 1903, 313; Bergey et al., Manual, 1st ed., 1923.)

Differs from *Serratia rubrica* in showing more luxuriant growth on potato and slower action in milk.

Habitat: Isolated from Mississippi river water.

23. **Serratia havaniensis** (Sternberg) Bergey et al. (*Bacillus havaniensis* Sternberg, Manual of Bacteriology, 1892, 718; Bergey et al., Manual, 1st ed., 1923, 95.)

Rod short, oval, 0.4 by 0.9 micron, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Circular, translucent, of blood-red color.

Gelatin stab: Opaque, carmine layer. No liquefaction.

Agar colonies: Opaque, becoming carmine red.

Agar slant: Red, glistening, with wavy margin.

Broth: Turbid, with pellicle.

Litmus milk: Unchanged. Orange pigment on surface.

Potato: Usually no growth, occasionally slight growth on old, dry medium.

No gas in dextrose or lactose; gas in sucrose.

No pigment formed at 37°C.

Indol not produced.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Intestinal canal.

24. **Serratia rosea** Bergey et al. (*Bacillus mycoides roseus* Scholl, see Grotenfeldt, Fortschrit, der Med., *7*, 1889, 46; Bergey et al., Manual, 1st ed., 1923, 96.)

Rods, from 2 to 10 microns in length. Non-motile. Gram-negative.

Gelatin colonies: Minute, white, creased and corrugated.

Gelatin stab: Dry, thick, corrugated, pink with arborescent growth in stab. No liquefaction.

Agar colonies: Small, pink, granular, with entire margin.

Agar slant: A salmon pink growth, becoming dull, dry, wrinkled, and assuming a vermilion color.

Broth: No turbidity.

Litmus milk: Salmon pink flakes floating on the surface after ten days; becoming alkaline.

Potato: Slow growth. Orange colored colonies, which become moist warty and salmon pink in color.

No gas in carbohydrate media.

Good growth and pigment formation at 37°C.

Indol not formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Soil.

25. **Serratia rubropertincta** (Grassberger) Bergey et al. (*Bacillus rubropertinctus* Grassberger, Münch. Med. Wochenschr., 1899, 343; Bergey et al., Manual, 1st ed., 1923, 96.)

Small rods: 1.5 to 3.0 microns in length. Old cultures are somewhat acid-fast. Non-motile. Gram-negative.

Gelatin colonies: Irregular, with crenate margin and folded surface. Red.

Gelatin stab: Surface growth like the colonies. No liquefaction.

Agar colonies: Minute, granular, becoming pink red.

Agar slant: Dry, lusterless, spreading, wrinkled, vermilion red.

Broth: Slightly turbid, with salmon-pink pellicle.

Litmus milk: No change in reaction. Pink surface growth.

Potato: Slow, orange-red, rough, moist, granular growth.

No gas in carbohydrate media.

Slight indol formation.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30–35°C.

Habitat: Isolated from butter.

26. **Serratia roseo-alba** (Sack) Bergey et al. (*Nitrobacter roseo-albus* Sack, Cent. f. Bakt., II Abt., *62*, 1924, 17; Bergey et al., Manual, 3rd ed., 1930, 125.)

Rods: 0.4 by 0.9 micron. Non-motile. Gram-positive.

Gelatin colonies: Circular, rose-colored.
Gelatin stab: No liquefaction.
Agar colonies: Small, circular ,rose-colored,entire.
Agar slant: Rose-colored streak.
Broth: Turbid with rose-colored sediment.
Nitrite litmus milk: Unchanged.
Potato: Small, orange-colored colonies.
Indol not formed.
Nitrate is formed from nitrite.
H_2S not formed.
Cellulose hydrolyzed.
Can obtain carbon from carbon dioxid, dextrose, levulose, lactose, sucrose, mannitol, cellulose, but not from carbonates.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

27. **Serratia bruntzii** (Nepeux) Bergey et al. (*Bacillus bruntzii* Nepeux, Jouve & Cie, Paris, 1920; Bergey et al., Manual, 3rd ed., 1930, 125.)
Rods: 0.3 to 0.5 by 1.25 to 1.5 microns, occurring singly and in pairs. Non-motile. Gram-negative. The cells store volutin and glycogen as reserve material.
Gelatin colonies: Circular, gray, smooth, contoured, glistening, undulate margin, becoming red.
Gelatin stab: No liquefaction.
Agar colonies: Circular, flat, smooth, contoured, radiate margin, vinous red.
Agar slant: Smooth, echinulate, butyrous, vinous red in color.
Broth: Turbid.
Litmus milk: Unchanged.
Potato.
Indol not formed.
Nitrates reduced to nitrites.
Acid in dextrose, levulose, maltose, lactose, sucrose, mannitol, dulcitol and glycerol.
Aerobic, facultative.
Optimum temperature 20° to 25°C.
Habitat: Water.

Genus II. Flavobacterium *Bergey et al., 1923.*

Rods of medium size, occurring in water and soil, forming a yellow to orange pigment on culture media. Characterized by feeble powers of attacking carbohydrates, occasionally forming acid from hexoses but no gas. Motile or non-motile. Generally Gram-negative.
The type species is *Flavobacterium aquatile* (Frankland) Bergey et al.

Key to the species of genus **Flavobacterium.**

A Motile. Flagella peritrichous.
- 1. Gelatin liquefied.
  - a. Growth on potato.
    - b. Milk unchanged in reaction.
      - c. Nitrates reduced.
        - d. Indol not formed.
          - 1. *Flavobacterium aquatile.*
          - 2. *Flavobacterium diffusum.*
          - 3. *Flavobacterium rigense.*
          - 4. *Flavobacterium schirokikhii.*
      - cc. Nitrates not reduced.
        - d. Indol not formed
          - 5. *Flavobacterium flavum.*
          - 6. *Flavobacterium devorans.*
          - 7. *Flavobacterium aurescens.*
    - bb. Milk neutral; coagulated.
      - c. Nitrates not reduced.
        - d. Indol not formed.
          - 8. *Flavobacterium synxanthum.*
      - cc. Nitrates reduced.
        - d. Indol not formed.
          - 9. *Flavobacterium rheni.*
    - bbb. Milk alkaline, peptonized.
      - c. Nitrates not reduced.
        - d. Indol not formed.
          - 10. *Flavobacterium sulfureum.*
          - 11. *Flavobacterium marinum.*
      - cc. Nitrates reduced.
        - d. Indol not formed.
          - 12. *Flavobacterium fucatum.*
    - bbbb. Milk acid.
      - c. Nitrates not reduced.
        - d. Indol not formed.
          - 13. *Flavobacterium harrisonii.*
          - 14. *Flavobacterium radiatum.*
          - 15. *Flavobacterium antenniforme.*
      - cc. Nitrates show slight reduction.
        - d. Indol not formed.
          - 16. *Flavobacterium balustinum.*
        - dd. Indol formed.
          - 17. *Flavobacterium suaveolens.*
    - bbbbb. Milk acid; coagulated.
      - c. Nitrates not reduced.
        - d. Indol not formed.

18. *Flavobacterium tremelloides.*
19. *Flavobacterium plicatum.*
20. *Flavobacterium aromaticum.*

cc. Nitrates reduced.
d. Indol not formed.

21. *Flavobacterium orchiditis.*

2. Gelatin not liquefied.
a. Growth on potato.
b. Milk unchanged.
c. Nitrates not reduced.
d. Indol not formed.

22. *Flavobacterium butyri.*
23. *Flavobacterium stolonatum*
24. *Flavobacterium flavescens.*

cc. Nitrates slowly reduced.

25. *Flavobacterium aurantiacum.*

bb. Milk alkaline.
c. Nitrates not reduced.
d. Indol not formed.

26. *Flavobacterium matazoonii.*

cc. Nitrates reduced.
d. Indol not formed.

27. *Flavobacterium maris*

bbb. Milk acid.
c. Nitrates not reduced.
d. Indol not formed.

28. *Flavobacterium lactis.*
29. *Flavobacterium aurantinum.*

aa. No growth on potato.
b. Milk unchanged.
c. Nitrates reduced.
d. Indol not formed.

30. *Flavobacterium denitrificans.*

cc. Nitrates not reduced.
d. Indol not formed.

31. *Flavobacterium invisibile.*

B. Motile. Flagella polar.
1. Gelatin liquefied.
a. Growth on potato.
b. Milk unchanged.
c. Nitrates reduced.
d. Indol not formed.

32. *Flavobacterium caudatum.*

bb. Milk coagulated; alkaline.
c. Nitrates not reduced.
d. Indol formed.

33. *Flavobacterium annulatum.*
34. *Flavobacterium ochraceum.*

cc. Nitrates reduced.
d. Indol formed.

35. *Flavobacterium trifolii.*
36. *Flavobacterium lasseuri.*
37. *Flavobacterium fermentans.*

2. Gelatin not liquefied.
a. Growth on potato.
b. Milk not coagulated.
c. Nitrates not reduced.
d. Indol not formed.

38. *Flavobacterium turcosum.*

bb. Milk coagulated.
c. Nitrates reduced.
d. Indol not formed.

39. *Flavobacterium cereviseae.*

dd. Indol formed.

40. *Flavobacterium xanthum.*

C. Motile. Flagellation not reported.
1. Gelatin liquefied.
a. Growth on potato.
b. Litmus milk (action not reported).
c. Indol not formed.

41. *Flavobacterium rhodomelae.*

bb. Litmus milk acid; slowly coagulated.
c. Indol not formed.

42. *Flavobacterium acetylicum.*

2. Gelatin not liquefied.
a. Growth on potato.
b. Litmus milk unchanged.
c. Indol formed.

43. *Flavobacterium halophilum.*

aa. Growth on potato not reported.
b. Litmus milk not coagulated.

44. *Flavobacterium morbificans.*

D. Non-motile.
1. Gelatin liquefied.
b. Litmus milk unchanged.
c. Nitrates not reduced.
d. Indol not formed.

45. *Flavobacterium brunneum.*
46. *Flavobacterium buccalis.*

cc. Action on nitrates not recorded.

47. *Flavobacterium sewanense.*

bb. Litmus milk reduced.
c. Nitrates not reduced.
d. Indol not formed.
48. *Flavobacterium arborescens.*

bbb. Milk alkaline.
c. Nitrates reduced.
d. Indol not formed.
49. *Flavobacterium fuscum.*
50. *Flavobacterium lutescens.*

bbbb. Milk coagulated; alkaline.
c. Nitrates not reduced.
d. Indol not formed.
51. *Flavobacterium esteroaromaticum.*
52. *Flavobacterium fecale.*
53. *Flavobacterium helvolum.*
54. *Flavobacterium decidiosum.*
55. *Flavobacterium racemosum.*

bbbbb. Milk acid.
c. Nitrates not reduced.
d. Indol not formed.
56. *Flavobacterium fulvum.*
57. *Flavobacterium dormitator.*

bbbbbb. Action in milk not reported.
c. Action on nitrates not reported.
d. Indol formation not reported.
58. *Flavobacterium polysiphoniae.*
59. *Flavobacterium droebacheuse.*
60. *Flavobacterium delesseriae.*
61. *Flavobacterium boreale.*
62. *Flavobacterium ceramicola.*

2. Gelatin not liquefied.
a. No growth on potato.
b. Milk unchanged.
c. Nitrates not reduced.
d. Indol not formed.
63. *Flavobacterium breve*

aa. Growth on potato.
b. Milk unchanged.
c. Nitrates not reduced.
d. Indol not formed.
64. *Flavobacterium solare.*
65. *Flavobacterium ovale.*

cc. Nitrates reduced.
d. Indol not formed.
66. *Flavobacterium flavotennae.*

bb. Milk acid.
c. Nitrates not reduced.
d. Indol formed.
67. *Flavobacterium lacunatum.*
aaa. Growth on potato not reported.
b. Growth in milk not reported.
68. *Flavobacterium salmonicolor.*

1. **Flavobacterium aquatile** (Frankland and Frankland) Bergey et al. (*Bacillus aquatilis* G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 381; Bergey et al., Manual, 1st ed., 1923, 100.)

Rods: 0.5 by 2.5 microns, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Center brownish, with radiate arrangement of bundles of threads.

Gelatin stab: Yellow surface growth. Saccate liquefaction.

Agar slant: Yellow, smooth, glistening.

Broth: Turbid, with gray sediment.

Litmus milk: Unchanged.

Potato: Limited, yellow streak.

Indol not formed.

Nitrates reduced to nitrites and ammonia.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Water.

2. **Flavobacterium diffusum** (Frankland and Frankland). Bergey et al. (*Bacillus diffusus*, G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 396; Bergey et al., Manual, 1st ed., 1923, 100.)

Rods: 0.5 by 1.5 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Thin, bluish-gray, spreading, later faint yellow.

Gelatin stab: Thin, glistening, yellowish-gray surface growth. Slow crateriform liquefaction.

Agar slant: Thin, light yellow, glistening.

Broth: Turbid, with grayish-yellow sediment.

Litmus milk: Unchanged.

Potato: Thin, smooth, greenish-yellow glistening growth.

Indol not formed.

Nitrates reduced to nitrites.

Slight acidity in dextrose.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Soil and water.

3. **Flavobacterium rigense** Bergey et al. (*Bacillus brunneus rigensis* Bazarewski, Cent. f. Bakt., II Abt., *15*, 1905, 1; Bergey et al., Manual, 1st ed., 1923, 100.)

Rods: 0.75 by 1.7 to 2.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, entire to undulate, grayish-white, homogeneous.

Gelatin stab: Smooth, yellowish surface growth. Infundibuliform liquefaction.

Agar slant: Narrow, whitish streak, becoming yellowish-brown, spreading.

Broth: Turbid, with pellicle and brownish sediment.

Litmus milk: Unchanged.

Potato: Yellow, spreading growth. The medium turns brown.

Indol not formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

4. **Flavobacterium schirokikhii** (H. Jensen) Bergey et al. (Schirokikh, Cent. f. Bakt., II Abt., *2*, 1896, 205; *Bacterium schirokikhi*, H. Jensen, ibid., *4*, 1898, 409; Bergey et al., Manual, 1st ed., 1923, 101.)

Rods: 0.5 by 1.5 microns, occurring singly and in short chains. Motile possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Liquefaction with bluish fluid containing yellow granules.

Gelatin stab: Rapid infundibuliform liquefaction.

Agar colonies: Stellate, with yellowish center, and thin bluish periphery.

Agar slant: White, folded, spreading, slimy.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Yellowish layer.

Indol not formed.

Nitrates reduced to nitrites and nitrogen.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Isolated from horse manure.

5. **Flavobacterium flavum** (Fuhrmann) Bergey et al. (*Bacillus flavus* Fuhrmann, Cent. f. Bakt., II Abt., *19*, 1907, 117; Bergey et al., Manual, 1st ed., 1923, 101.)

Rods: 0.6 to 0.8 by 1.0 to 1.2 microns, occurring singly and in pairs. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, circular, light yellow, entire.

Gelatin stab: Slow liquefaction.

Agar slant: Light yellow, smooth, glistening, undulate.

Broth: Turbid, with pellicle and yellow sediment.

Litmus milk: Unchanged.

Potato: Honey yellow layer.

Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 32° to 35°C.
Habitat: Isolated from beer.

6. **Flavobacterium devorans** (Zimmermann) Bergey et al. (*Bacillus devorans* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, 1890, 48; Bergey et al., Manual, 1st ed., 1923, 102.)

Rods: 0.7 by 0.9 to 1.2 microns, occurring singly, in pairs and chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, white, granular to filamentous, becoming yellowish-gray.

Gelatin stab: Slow, infundibuliform liquefaction.
Agar slant: Thin, gray, spreading.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Yellowish-gray streak.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25° to 30°C.
Habitat: Water.

7. **Flavobacterium aurescens** (Ravenel) Bergey et al. (*Bacillus aurescens* Ravenel, Memoirs, Nat. Acad. Sci., *8*, 1896, 8; not *Bacillus aurescens* Frankland and Frankland, Philo. Trans. Roy. Soc. London, B, 1888, 271; Bergey et al., Manual, 1st ed., 1923, 102.)

Rods: 0.5 by 1.0 to 1.5 microns, spindle shaped, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Minute, whitish, becoming brownish, entire.

Gelatin stab: Slight, yellow surface growth. Slow crateriform liquefaction.

Agar colonies: Circular, flat, glistening, pale yellow, entire.
Agar slant: Thin, yellowish, limited, becoming golden yellow, lobate.
Broth: Slightly turbid with dense flocculent sediment.
Litmus milk: Unchanged in reaction. Litmus reduced.
Potato: Thick, yellow, moist, spreading, becoming orange-yellow.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 36°C.
Habitat: Soil.

8. **Flavobacterium synxanthum** (Ehrenberg) Bergey et al. (*Vibrio synxanthus* Ehrenberg, Verhandl. d. Berl. Akad., 1840, 202; *Vibrio xanthogenes* Fuchs, Magazin, f. d. ges. Tierheilkde, *7*, 1841, 193; *Bacterium xanthinum* Schroeter, Cohn's Beitrage z. Biol. d. Pflanzen, *1*, Heft 2, 1872,

120; *Bacillus synxanthus* Flügge, Die Mikroorganismen, 1886, 290; Bergey et al., Manual, 1st ed., 1923, 102.)* Bergey et al., Manual, 1st ed., 1923, 102, gives *Bacterium xanthogenes* as a synonym.

Rods: 0.8 by 1.0 to 3.0 microns, occurring singly. Motile. Gram-negative.

Gelatin colonies: Thin, bluish-gray, glistening.

Gelatin stab: Liquefied.

Agar colonies: Large, spreading, transparent.

Agar slant: White, becoming thick brownish.

Broth: Turbid, with gray pellicle and sediment.

Litmus milk: Coagulated; peptonized; canary-yellow; becoming alkaline, ropy.

Potato: Dirty-gray, glistening.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose and galactose.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Isolated from ropy milk.

9. **Flavobacterium rheni** (Chester) Bergey et al. (Rhine water bacillus of Burri, Frankland and Frankland, Microorganisms in Water, 1894, 483; *Bacillus rheni* Chester, Manual Determ. Bact., 1901, 251; Bergey et al., Manual, 1st ed., 1923, 103.)

Rods: 0.7 by 2.5 to 3.5 microns, with rounded ends, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Convex, colorless, transparent, becoming yellowish.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Small, grayish, smooth, convex, entire.

Agar slant: Grayish, smooth, lobate.

Broth: Turbid, with orange colored pellicle and sediment.

Litmus milk: Soft coagulum, becoming slightly alkaline with yellow ring.

Potato: Moist, glistening, thin, flat, orange.

Indol not formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Water.

10. **Flavobacterium sulfureum** Bergey et al. (*Bacterium punctans sulfureum* Zettnow, Cent. f. Bakt., I Abt., Orig., *77*, 1916, 222; Bergey et al., Manual, 1st ed., 1923, 103.)

Rods: 0.5 to 0.7 by 0.7 to 1.5 microns. Motile, possessing peritrichous flagella. Gram-positive.

Gelatin colonies: Very small, barely visible, becoming brownish-yellow, granular.

Gelatin stab: Crateriform liquefaction.

Agar slant: Sulfur-yellow.
Broth: Turbid.
Litmus milk: Alkaline; peptonized.
Potato: Sulfur-yellow streak.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Air.

11. **Flavobacterium marinum** Harrison. (Canadian Jour. of Research, *1*, 1929, 234.)

Rods: 0.8 by 1.2 to 1.3 microns, with rounded ends. Occur singly and in pairs. Motile with 4 to 5 peritrichous flagella. Encapsulated. Gram variable. Show blue granules in Gram-negative rods.

Gelatin colonies: Circular, iridescent whitish margin and pale yellow center.

Gelatin stab: Saccate to stratiform liquefaction.

Agar colonies: Circular, pale yellow, smooth, convex, granular, reticulate edge.

Agar slant: Amber-yellow, slightly raised, spreading, smooth, glistening, transparent.

Broth: Cloudy with sediment.

Litmus-milk: Alkaline.

Potato: Abundant amber-yellow, becoming dirty yellow, spreading, glistening.

Indol not formed.

Nitrates not reduced.

Traces of ammonia formed.

Faint acidity in dextrose. No action on lactose or sucrose.

Loeffler's blood serum not liquefied. H_2S not formed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Isolated from living halibut obtained at 30 to 50 fathoms. Pacific Ocean.

12. **Flavobacterium fucatum** Harrison. (Canadian Jour. of Research, *1*, 1929, 232.)

Rods: 0.8 to 1.0 by 2.5 to 3.5 microns, slightly bent, with rounded ends. Non-motile. Gram-negative.

Gelatin colonies: Circular, yellow, entire, paler at edges.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Circular, buff-yellow, smooth, shiny, convex to pulvinate, granular, entire.

Agar slant: Moderate, light buff-yellow, spreading, shiny, smooth.

Broth: Cloudy, becoming clear, pellicle and yellow sediment.

Litmus milk: Alkaline. Peptonized. Yellow sediment.

Potato: Abundant, pale buff-yellow, smooth, spreading, becoming orange-yellow.

Indol not formed.

Nitrates reduced to nitrites.

Traces of ammonia formed.

No acid in dextrose, lactose or sucrose.

Loeffler's blood serum not liquefied.

H_2S not formed.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Isolated from living halibut obtained at 30 to 50 fathoms. Pacific Ocean.

13. **Flavobacterium harrisonii** Bergey et al. (Harrison, Rev. gén du Lait, *5*, 1905, 73, 129, 145; *Bacillus lactis harrisonii* Conn, Esten and Stocking, Ann. Rept. Storrs Agr. Exp. Sta., 1906, 169; Bergey et al., Manual, 1st ed., 1923, 104.)

Rods: 0.25 to 0.75 by 0.3 to 3.5 microns, occurring singly and occasionally in short chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, gray, glistening, lobular, brownish.

Gelatin stab: Villous growth in stab. Slow crateriform to napiform liquefaction.

Agar slant: Luxuriant, viscous, spreading, becoming dirty, citron-yellow.

Broth: Turbid, with ring and gelatinous sediment.

Litmus milk: Acid, becoming yellow, slimy, alkaline.

Potato: Luxuriant, yellow, spreading.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Slimy milk.

14. **Flavobacterium radiatum** Bergey et al. (*Bacillus radiatus aquatilis* Copeland, Report of Filtration Commission, Pittsburgh, 1899, 344; Bergey et al., Manual, 1st ed., 1923, 104.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Orange, raised, wrinkled, frimbriate.

Gelatin stab: Orange surface growth. Slow liquefaction.

Agar slant: Thin, moist, orange streak.

Broth: Turbid.

Litmus milk: Acid.

Potato: Orange, filiform growth.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 20°C.
Habitat: Water.

15. **Flavobacterium antenniforme** (Ravenel) Bergey et al. (*Bacillus antenniformis* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, p. 25; Bergey et al., Manual, 1st ed., 1923, 104.)

Rods: 0.6 by 3.0 to 4.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, with orange-brown center and colorless periphery composed of parallel filaments, dentate.

Gelatin stab: Liquefaction crateriform, becoming stratiform.
Agar slant: Thin, smooth, grayish.
Broth: Slightly turbid.
Litmus milk: Slightly acid; litmus reduced.
Potato: Dull gray, vesicular, folded, spreading growth.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Soil.

16. **Flavobacterium balustinum** Harrison. (Canadian Jour. of Research, *1*, 1929, 234.)

Rods: 0.6 by 2.0 to 4.0 microns, forming short chains. Motile. Gram-negative.

Gelatin colonies: Circular, bright yellow, entire.
Gelatin stab: Liquefied.
Agar colonies: Punctiform, cadmium-yellow, convex, shiny, transparent.

Agar slant: Egg yolk-yellow, semi-transparent streak, smooth, shiny, becoming brownish-yellow.

Broth: Cloudy, with yellow sediment.
Litmus milk: Slightly acid with yellow sediment.
Potato: Scant yellow growth.
Indol not formed.
Nitrates show trace of reduction.
Ammonia not formed.
Faint acidity in dextrose. No action on lactose or sucrose.
Loeffler's blood serum not liquefied.
H_2S not formed.
Aerobic, facultative.
Optimum temperature 20° to 25°C.
Habitat: Isolated from living halibut obtained at 30 to 50 fathoms. Pacific Ocean.

17. **Flavobacterium suaveolens** Soppeland. (Jour. of Agr. Research, *28*, 1924, 275.)

Rods with rounded ends, occurring singly and in pairs, 0.6 to 0.8 by 1.0 to 1.2 microns. Motile, with peritrichous flagella. Gram-negative.

Gelatin stab: Rapid stratiform liquefaction. Medium becomes brown.

Agar colonies: Small, circular, smooth, yellow, amorphous, undulate margin.

Agar slant: Moderate, flat, glistening, opaque, butyrous, yellow, with aromatic odor.

Broth: Turbid with scanty sediment. Aromatic odor, becoming cheesy.

Litmus milk: Peptonized. Alkaline.

Potato: Abundant, yellow glistening.

Indol formed.

Nitrates are reduced.

H_2S formed.

Slight acid in dextrose, sucrose and glycerol.

Starch hydrolyzed.

Blood serum is liquefied.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Dairy wastes.

18. **Flavobacterium tremelloides** (Tils) Bergey et al. (*Bacillus tremelloides* Tils, Zeitschr. f. Hyg., *9*, 1890, 292; Bergey et al., Manual, 1st ed., 1923, 105.)

Rods· 0.25 by 1.0 to 1.2 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, yellow, smooth, spreading, entire.

Gelatin stab: Slow liquefaction.

Agar colonies.

Agar slant: Thin, moist, orange, spreading growth.

Broth: Turbid with pellicle.

Litmus milk: Acid; coagulated.

Potato: Limited yellow growth.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Habitat: Water.

19. **Flavobacterium plicatum** (Copeland) Bergey et al. (*Bacillus plicatus*, Rept. Filtration Commission, Pittsburgh, 1899, 348; Bergey et al., Manual, 1st ed., 1923, 105; Not *Bacillus plicatus* Zimmerman, Bakt. unserer Trink- und Nutzwässer, Chemnitz, 1890, 54.)

Rods: 0.25 by 1.0 micron, with rounded ends, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, yellow, lobed.

Gelatin stab: Orange surface growth; liquefied.

Agar slant: Orange, filiform growth.

Broth: Turbid.
Litmus milk: Acid, coagulated, peptonized.
Potato: Deep orange, filiform growth.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Water.

20. **Flavobacterium aromaticum** (Pammel) Bergey et al. (*Bacillus aromaticus* Pammel, Bull. No. 21, Iowa Agr. Exper. Sta., 1893, 792; Cent. f. Bakt., II Abt., *2*, 1906, 633; Bergey et al., Manual, 1st ed., 1923, 105.)

Rods: 0.3 to 0.45 by 0.9 to 1.2 microns, with rounded ends, occurring singly and in pairs. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin stab: Infundibuliform liquefaction.
Agar colonies: Thin, yellowish, white, smooth.
Agar slant: Whitish, spreading, becoming yellowish-white, with tinge of brown.
Broth: Turbid, with slight pellicle and yellowish-white sediment.
Litmus milk: Acid; coagulated; peptonized.
Potato: Yellowish-white streak.
Indol not formed.
Nitrates not reduced.
Acid formed in lactose; acid and gas in dextrose and sucrose
Cultures have odor of butyl alcohol.
Microaerophilic.
Optimum temperature 25°C.
Habitat: Isolated from cabbage.

21. **Flavobacterium orchiditis** Sherwood, Edwin and Marts. (Amer. Jour. Diseases of Children, *45*, 1933, 446; Jour. Kansas Med. Soc., *34*, 1933, No. 6.)

Short rods with rounded ends showing bipolar staining, occurring singly and in short chains. Motile, Gram-negative. Capsulated.

Gelatin stab: Rapid craterioform liquefaction.
Agar colonies: Circular, slightly raised, thick opaque, slightly brown in 72 hrs. with somewhat irregular margin. Growth on blood agar plates shows hemolysis and methemoglobin.
Glycerine agar slant: Thick, mucoid, cream colored.
Broth: Turbid with pellicle.
Litmus milk: Coagulation with acid production and peptonization.
Potato: Vigorous growth, slightly brown in 72 hours.
Indol not formed.
Nitrates reduced.
Blood serum liquefied.
Hydrogen sulphide not produced.

Acid in dextrose, lactose, maltose, sucrose and mannitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated by Sherwood from a case of meningitis.

Pathogenicity: Quite virulent for guinea pigs and rabbits. Males develop acute orchitis following intravenous inoculation. There is considerable evidence that suggests that a soluble toxin is produced.

Note: Sherwood et al. consider that *Flavobacterium orchiditis* resembles *Bacillus whitmori* (*Actinobacillus pseudomallei*) culturally and in many other respects.

22. **Flavobacterium butyri** Bergey et al. (*Bacillus aromaticus butyri* Sewerin, Cent. f. Bakt., II Abt., *11*, 1903, 264; Bergey et al., Manual, 1st ed., 1923, 106.)

Rods: 0.7 to 0.8 by 1.5 to 2.0 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, light yellow, finely granular.

Gelatin stab: Translucent, grayish-white surface growth. No liquefaction.

Agar colonies: Circular, yellowish-brown, periphery lighter in color, finely granular.

Agar slant: Grayish-white, smooth, moist, glistening.

Broth: Turbid, with thin pellicle.

Litmus milk: Unchanged.

Potato: Light yellow, spreading, smooth, glistening.

Indol not formed.

Nitrates not reduced.

Forms an agreeable odor.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from sour cream.

23. **Flavobacterium stolonatum** (Adametz) Bergey et al. (*Bacillus stolonatus* Adametz, Mitt. Oest. Versuchstat. f. Braueri u. Mälz., Wien, 1888, 884; Bergey et al., Manual, 1st ed., 1923, 106.)

Rods: 0.5 to 0.6 by 1.2 to 1.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Whitish to brownish, capitate.

Gelatin stab: Whitish surface growth. No liquefaction.

Agar colonies: Whitish, rhizoid.

Agar slant: Whitish, spreading to rhizoid.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Dirty white streak.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30°C.
Habitat: Water.

24. **Flavobacterium flavescens** (Pohl) Bergey et al. (*Bacillus flavescens* Pohl, Cent. f. Bakt., *11*, 1892, 141; Frankland and Frankland, Microorganisms in Water, 1894, 448; Bergey et al., Manual, 1st ed., 1923, 107.)

Rods: 0.8 by 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Small, yellow, granular.
Gelatin stab: Yellow surface growth. No liquefaction.
Agar colonies: Small, flat, smooth, yellow, entire.
Agar slant: Scant, filiform, yellow.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Slimy, yellow, spreading.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

25. **Flavobacterium aurantiacum** (Frankland and Frankland) Bergey et al. (*Bacillus aurantiacus* G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 390; Bergey et al., Manual, 1st ed., 1923, 107.)

Rods: 0.6 by 1.8 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Opaque, homogeneous, moist, smooth, raised, orange.
Gelatin stab: Orange surface growth. No liquefaction.
Agar colonies: Small, circular, smooth, raised.
Agar slant: Limited, orange growth.
Broth: Turbid, with thin orange pellicle and sediment.
Litmus milk: Unchanged.
Potato: Thick, glistening, reddish-orange.
Indol not formed.
Nitrates may be slowly reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

26. **Flavobacterium matazoonii** (Chester) Bergey et al. (Culture 46 of Conn, Storrs Agr. Exper. Sta. Rept., 1894, 80; *Bacillus matazooni* Chester, Determinative Bacteriology, 1901, 236; Bergey et al., Manual, 1st ed., 1923, 107.)

Rods: 0.4 by 0.8 micron, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Circular, whitish to yellowish, crenate margin.
Gelatin stab: Whitish to yellowish surface growth. No liquefaction.
Agar colonies: Thin, flat, smooth, yellowish-white.

Agar slant: Thin, whitish to yellowish streak.
Broth: Turbid, with yellowish sediment.
Litmus milk: Slow coagulation; alkaline.
Potato: Yellowish-brown streak.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Milk.

27. **Flavobacterium maris** Harrison. (Canadian Jour. Research, *1*, 1929, 232.)

Rods: 0.7 to 0.8 by 1.0 to 1.2 microns, occurring singly and in pairs. At 37°C. coccoid. Non-motile. Encapsulated. Gram-positive.

Gelatin colonies: Punctiform, red-orange, granular, entire.

Gelatin stab: Red-orange surface growth, filiform growth in stab. No liquefaction.

Agar colonies: Circular, orange-yellow, smooth, glistening, convex.

Agar slant: Moderate, orange-yellow, becoming cadmium-orange, to red-orange, spreading, glistening.

Broth: Clear with orange pellicle and sediment.

Litmus milk: At first faintly alkaline, becoming faintly acid with orange sediment.

Potato: Scant growth.
Indol not formed.
Nitrates reduced to nitrites.
Traces of ammonia formed.
Faint acidity in dextrose. No action on lactose or sucrose.
Loeffler's blood serum not liquefied.
H_2S not formed.
Aerobic, facultative.
Optimum temperature 20° to 25°C.

Habitat: Isolated from living halibut obtained at 30 to 50 fathoms. Pacific Ocean.

28. **Flavobacterium lactis** Bergey et al. (*Bacillus aromaticus lactis* Grimm, Cent. f. Bakt., II Abt., *8*, 1902, 584; *Bacillus aromaticus* Grimm, *ibid.*, 589; not *Bacillus aromaticus* Pammel, Bull. 20, Iowa Agr. Exp. Sta., 1893, 792; not *Flavobacterium aromaticum* Bergey et al., Manual, 1st ed., 1923, 105; *ibid.*, 108.)

Rods: 0.7 to 1.0 by 3.5 to 4.0 microns, occurring singly in pairs and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, light yellow, slimy. Concentrically ringed, undulate.

Gelatin stab: Slimy surface growth. No liquefaction.
Agar slant: Slimy, yellowish, smooth, moist.
Broth: Turbid, with abundant sediment.
Litmus milk: Slightly acid.

Potato: Thick, slimy, brownish, with yellowish margin.
Indol not formed.
Nitrates not reduced.
Cultures have pleasant odor.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Isolated from milk.

29. **Flavobacterium aurantinum** (Hammer) Bergey et al. (*Bacillus aurantinus* Hammer, Research Bull. No. 20, Iowa Agr. Exp. Sga., 1915, 149; Bergey et al., Manual, 1st ed., 1923, 107.)

Rods: 0.3 by 1.5 microns, occurring singly and in pairs. Motile. Gram-negative.

Gelatin stab: Yellow, wrinkled surface growth. No liquefaction
Agar colonies: Small, raised, yellow, wrinkled.
Agar streak: Filiform, yellow, wrinkled.
Broth: Slightly turbid, with yellow, flocculent sediment.
Litmus milk: Acid; coagulated.
Potato: Bright yellow, glistening.
Indol not formed.
Nitrates are reduced.
Acid in dextrose, levulose, galactose and maltose.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Milk.

30. **Flavobacterium denitrificans** (Lehmann and Neumann) Bergey et al. (*Bacillus denitrificans I* Burri and Stutzer, Cent. f. Bakt. II. Abt., *1*, 1895, 360; *Bacterium denitrificans* Lehmann and Neumann, Bakt. Diagnostik, 1898, 408; Bergey et al., Manual, 1st ed., 1923, 109.)

Rods: 0.5 by 1.0 to 2.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, dry, white with translucent edge and erose margin.

Gelatin stab: Thin, white to yellowish-white surface growth. Filamentous growth in stab. No liquefaction.

Agar colonies: Thin, flat, colorless, erose margin.
Agar slant: Limited, yellowish-white streak, spreading.
Broth: Turbid, with pellicle.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 25°C
Habitat: Soil.

31. **Flavobacterium invisibile** (Vaughan) Bergey et al. (*Bacillus invisibilis* Vaughan, American Jour. Med. Sci., 1892, 107; Bergey et al., Manual, 1st ed., 1923, 109.)

Rods: 0.6 to 0.7 by 1.2 to 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Pale yellow, burr-like with irregular margin.

Gelatin stab: Scanty growth on surface. Good growth in stab. No liquefaction.

Agar colonies: White, convex, smooth, serrate.

Agar slant: Limited, thick, white streak.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: No growth.

Indol not formed.

Nitrates not reduced

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Water.

32. **Flavobacterium caudatum** (Wright) Bergey et al. (*Bacillus caudatus* Wright, Memoirs Nat. Acad. of Sci., *7*, 1895, 444; *Pseudomonas caudatus* Conn, Jour. Agr. Research, *16*, 1919, 333; Bergey et al., Manual, 1st ed., 1923, 109.

Rods, small slender, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Yellow, translucent, smooth, undulate.

Gelatin stab: Villous growth in stab. Crateriform liquefaction.

Agar slant: Yellow to orange, glistening, translucent, slightly spreading.

Broth: Turbid, with yellowish sediment.

Litmus milk: Slight reduction of litmus.

Potato: Dark yellow, raised, rough, spreading.

Indol not formed.

Nitrates reduced to nitrites and ammonia.

Starch is digested.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Water.

33. **Flavobacterium annulatum** (Wright) Bergey et al. (*Bacillus annulatus* Wright, Memoirs Nat. Acad. of Sci., *7*, 1895, 443; *Pseudomonas annulata* Chester, Determinative Bacteriology, 1901, 315; Relationship to *Bacillus annulatus* Zimmermann uncertain. Die Bakt. unserer Trink- und Nutzwässer, Chemnitz, 1890, 30; Bergey et al., Manual, 1st ed., 1923, 110.)

Small rods, occurring singly and in pairs. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, with indistinct margin and yellowish center.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Small, yellowish, smooth, glistening.
Agar slant: Yellowish, translucent, glistening.
Broth: Turbid, with yellow pellicle.
Litmus milk: Coagulated; litmus reduced; alkaline.
Indol is formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

34. **Flavobacterium ochraceum** (Zimmermann) Bergey et al. (*Bacillus ochraceus* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, 1890; *Pseudomonas ochracea* Chester, Determinative Bacteriology, 1901, 316, 60; Bergey et al., Manual, 1st ed., 1923, 110.)

Rods: 0.5 to 0.8 by 1.2 to 3.6 microns, occurring singly. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Grayish, slightly raised, with slightly fringed margin, granular.

Gelatin stab: Yellowish to yellow-gray surface growth. Infundibuliform liquefaction.

Agar colonies: Thin, flat, yellowish, smooth.
Agar slant: Thin, yellowish-gray to ochraceous growth.
Broth: Slightly turbid, with slight pellicle and considerable sediment.
Litmus milk: Medium becomes slimy; alkaline.
Potato: Ochre-yellow streak.
Indol is formed.
Nitrates not reduced.
H_2S is formed.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Water.

35. **Flavobacterium trifolii** (Huss) Bergey et al. (*Pseudomonas trifolii* Huss, Cent. f. Bakt., II Abt., *19*, 1907, 50; Bergey et al., Manual, 1st ed., 1923, 111.)

Rods: 0.5 to 0.7 by 0.75 to 2.0 microns, occurring singly, in pairs and in chains. Motile, possessing a single polar flagellum. Gram-negative.

Gelatin colonies: Convex, smooth, moist, glistening, grayish-yellow.
Gelatin stab: Napiform liquefaction.
Agar colonies: Small, circular, grayish, becoming brownish-yellow.
Agar slant: Yellowish, becoming brownish-yellow streak, lacerate margin.

Broth: Turbid, with grayish-yellow pellicle and sediment.
Litmus milk: Slowly coagulated; alkaline; with yellow ring.
Potato: Thick, yellowish, flat, smooth, glistening.
Indol is formed.
Nitrates reduced to nitrites.

Cultures have an agreeable odor.
Volutin formed.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from clover hay.

36. **Flavobacterium lasseuri** Bergey et al. (Bacillus le monnieri Lasseur, C. R. Soc. de Biol., *74*, 1912, 47; Bul. de la Soc. des Sci. de Nancy, 1924; Bergey et al., Manual, 3rd ed., 1930, 144.)

Rods: 0.5 to 0.9 by 1.4 to 2.8 microns, occurring singly and in pairs. Cytoplasm yellowish-brown. Motile with a single polar flagellum. Gram-negative.

Gelatin colonies (Dextrose): Circular with blue center, a granular, yellow zone and a peripheral green zone. Rapid liquefaction with blue crystals.

Gelatin stab: Liquefied.

Agar colonies: Circular, yellowish, lobate margin.

Agar slant: Yellowish streak, smooth, glistening.

Broth: Turbid with thin pellicle.

Litmus milk: After 48 hours the surface of the milk becomes yellow to cream color turning blue. A soft coagulum is formed.

Potato: Raised growth, Prussian blue in color, with metallic luster.

Indol is formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 22° to 25°C.

Habitat: Water.

37. **Flavobacterium fermentans** (von Wolzogen Kühr) *comb. nov.* (*Pseudomonas fermentans* von Wolzogen Kühr, Cent. f. Bakt., II Abt., *85*, 1932, 228.)

Rods: 0.4 to 0.6 by 1.7 to 3.4 microns, with rounded ends, occurring singly and in pairs. Motile, with a single polar flagellum. Gram-negative.

Gelation colonies: Circular, grayish, with rapid liquefaction.

Gelatin stab: Liquefaction crateriform.

Agar colonies: Circular, slightly convex, opaque, gray by reflected, and light-brown by transmitted light.

Agar slant: Gray, becoming yellowish.

Broth: Turbid with pellicle.

Litmus milk: Acid.

Potato: Gray to yellowish growth.

Indol is formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, lactose, sucrose and starch.

Acetyl-methyl-carbinol is formed.

Ammonia is formed from peptone and asparagin.

H_2S is formed.

Starch is hydrolyzed.
Lipase is formed.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from fly larvae (*Chironomus plumosus*) and from filtered water.

38. **Flavobacterium turcosum** (Zimmermann) Bergey et al. (*Bacillus turcosus* Zimmermann, Bakt. unserer Trink.- und Nutzwässer, Chemnitz, *2*, 1894, 32; *Pseudomonas turcosa* Chester, Determinative Bacteriology, 1901, 317; Bergey et al., Manual, 1st ed., 1923, 111.)
Rods: 0.2 to 0.3 by 0.3 to 1.5 microns, occurring singly. Motile, possessing a single polar flagellum. Gram-negative.
Gelatin colonies: Small, translucent, intense yellow.
Gelatin stab: Small, yellow, convex surface growth, with slight greenish tint. No liquefaction.
Agar slant: Scanty, intense yellow streak.
Broth: Slightly turbid with yellow sediment.
Litmus milk: No coagulation. Yellow sediment.
Potato: Scanty, dry, glistening, greenish-yellow.
Indol is not formed.
Nitrates not reduced.
Acid from dextrose. Slight action on sucrose.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water, sea water.

39. **Flavobacterium cereviseae** (Fuhrmann) Bergey et al. (*Pseudomonas cereviseae* Fuhrmann, Cent. f. Bakt., II Abt., *16*, 1906, 309; Bergey et al., Manual, 1st ed., 1923, 111.)
Rods: Straight and slightly curved, 0.6 by 1.5 to 2.0 microns, occurring singly and in chains. Motile, possessing four to six polar flagella. Gram-negative.
Gelatin colonies: Circular, white, slightly contoured, becoming brownish-yellow.
Gelatin stab: Slight yellowish growth in stab. No liquefaction.
Agar colonies: Thin, spreading, contoured.
Agar slant: Moist, glistening, thin, whitish-yellow, spreading, contoured.
Broth: Turbid, with grayish-white pellicle and large amount of sediment.
Litmus milk: Slow coagulation.
Potato: Brown, spreading growth.
Indol not formed.
Nitrates reduced to nitrites.
Gas formed in dextrose media, the gas consisting of 50 per cent CO_2, 39 per cent H_2, 8.5 per cent CH_4, and 2.5 per cent N_2.
Aerobic, facultative.

Optimum temperature 30°C.
Habitat: Isolated from beer.

40. **Flavobacterium xanthum** (Zettnow) Bergey et al. (*Pseudomonas xanthe* Zettnow, Cent. f. Bakt., I Abt., Orig. *77*, 1915, 220; *Flavobacterium zettnowii* Bergey et al., Manual, 1st ed., 1923, 112; Bergey et al., Manual, 3rd ed., 1930, 145.)

Rods: 0.5 to 0.6 by 0.4 to 1.4 microns. Motile, possessing long polar flagella. Gram-negative.

Gelatin colonies: Circular, yellow, granular.

Gelatin stab: Whitish-yellow surface growth. Saccate liquefaction.

Agar slant: Dark yellow, glistening, with dark yellow sediment in water of condensation.

Broth: Turbid.

Litmus milk: Slightly acid. Litmus reduced.

Potato: Greenish-yellow growth.

Indol formed.

Nitrates are reduced.

Acid formed in dextrose.

Starch hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Air contamination, also isolated from buttermilk.

41. **Flavobacterium rhodomelae** (Lundestad) Bergey et al. (*Bacterium rhodomelae* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 331; Bergey et al., Manual, 3rd ed., 1930, 146.)

Rods with rounded ends, 0.5 to 0.8 by 1.2 to 2.5 microns, occurring singly, in pairs, and at times in short chains. Motile. Gram-negative.

Fish-gelatin colonies: Circular, slightly glistening, opaque, white.

Fish-gelatin stab: Rapid, infundibuliform liquefaction.

Sea-weed agar colonies: Circular, flat, thin, transparent, glistening, entire. Agar is dissolved.

Dextrose agar slant: Moderate, white, becoming orange-yellow, flat, undulate margin, opaque, glistening.

Broth: Turbid, with pellicle, and grayish-yellow, slimy sediment.

Litmus milk.

Potato.

Indol not formed.

Nitrates not reduced.

Very slight hydrolysis of starch.

No action on carbohydrates.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Sea water of Norwegian Coast.

42. **Flavobacterium acetylicum** Levine and Soppeland. (Bul. 77, Engineering Exp. Sta., Iowa State Agricultural College, 1926, 46.)

Rods: 0.9 by 1.1 microns, with rounded ends, occurring singly and in pairs. Motile. Gram-positive.

Gelatin stab: Stratiform liquefaction.

Agar colonies: Irregular in form, yellow, smooth, flat, amorphous, entire.

Agar slant: Abundant echinulate growth, flat, peach yellow, smooth, butyrous.

Broth: Ring growth on surface. Turbid, with scant sediment.

Litmus milk: Slight acidity, with granular curd. Peptonization. Litmus reduced.

Potato: Moderate growth, orange.

Indol not formed.

Nitrates not reduced.

Starch hydrolyzed.

Blood serum liquefied.

Acid in dextrose with formation of acetyl-methyl-carbinol.

Aerobic, facultative.

Optimum temperature 22°C.

Habitat: Isolated from skimmed milk.

43. **Flavobacterium halophilum** Bergey et al. (Culture No. 30 of Baranik Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 147.)

Rods: 0.5 by 1.5 to 2.5 microns to 1.3 by 2.5 microns. Motile. Gram-negative.

Gelatin stab: Surface growth apricot colored. No liquefaction.

Agar colonies: Circular, yellowish-white, folded with serrate margin.

Agar slant: Apricot red to yellow streak, folded.

Broth: Turbid with yellow sediment, and apricot-colored pellicle.

Litmus milk: Unchanged.

Potato: Apricot-colored, glistening layer.

Indol formed.

Nitrates not reduced.

Ammonia formed.

H_2S formed.

Growth occurs in media with 25 per cent NaCl.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Sea water.

44. **Flavobacterium morbificans** Bergey et al. (*Bacillus bovis morbificans* Basenau, Arch. f. Hyg., *20*, 1894, 280; Bergey et al., Manual, 3rd ed., 1930, 147.)

Rods: 0.3 to 0.4 by 1.0 to 1.2 microns, occurring singly and in pairs. Motile. Gram-negative.

Gelatin stab: Yellowish-white surface growth. No liquefaction.
Agar colonies: Yellowish-white, circular.
Agar slant: Grayish-white streak, glistening.
Broth: Turbid with thin, flat, pellicle, becoming wrinkled, with flocculent sediment.
Litmus milk: No coagulation.
Potato: Moist, yellowish streak.
Indol.
Nitrates.
Acid and gas in dextrose.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from septicemic condition in a cow.

45. **Flavobacterium brunneum** (Copeland) Bergey et al. (*Bacillus brunneus* Copeland, Rept. Filtration Commission, Pittsburgh, 1899, 348; Bergey et al., Manual, 1st ed., 1923, 112.)
Rods: 0.5 by 1.0 micron, occurring singly and in pairs. Non-motile. Gram-negative.
Gelatin colonies: Small, flesh-colored to brown.
Gelatin stab: Brown surface growth. Crateriform liquefaction.
Agar slant: Very thin, glistening, grayish-yellow, filiform.
Broth: Clear.
Litmus milk: Unchanged.
Potato: Reddish-brown streak.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30° to 35°C
Habitat: Water.

46. **Flavobacterium buccalis** (Vignal) Bergey et al. (*Bacillus buccalis* Vignal, Arch. Physiol., *8*, 1886; Bergey et al., Manual, 1st ed., 1923, 113.)
Rods: 0.5 by 1 micron, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: Circular, raised, yellowish.
Gelatin stab: Crateriform to infundibuliform liquefaction. Yellowish-white, beaded growth in stab.
Agar slant: Smooth, yellow, filiform.
Broth: Turbid, with iridescent pellicle.
Litmus milk: Unchanged.
Potato: Thin, yellowish, becoming brownish.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Isolated from saliva.

47. **Flavobacterium sewanense** (Kalantarian and Petrossian) *comb. nov.* (*Bacterium sewanense* Kalantarian and Petrossian, Cent. f. Bakt., II Abt., *85*, 1932, 431.)

Rods: 1.0 to 2.0 by 4.0 to 5.0 microns on agar, on other media they are smaller. Ends rounded, occurring singly and in pairs. Non-motile. Gram.

Gelatin stab: Slow liquefaction.

Agar colonies: Circular, raised, glistening, dirty white. Yellow on microscopic examination.

Agar slant: Abundant, yellow, glistening, raised.

Broth: Turbid. Pellicle is formed in old cultures.

Litmus milk: Unchanged.

Potato: Yellow, raised, glistening with darkening of the medium.

Indol not formed.

Crystals of calcium carbonate form in old cultures.

Aerobic.

Optimum temperature 20°C.

Habitat: Sea water.

48. **Flavobacterium arborescens** (Frankland and Frankland) Bergey et al. (*Bacillus arborescens* G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 379; Bergey et al., Manual, 1st ed., 1923, 113.)

Rods: 0.5 by 2.5 microns, occurring singly and in chains. Non-motile. Gram-negative.

Gelatin colonies: Radiate branching filaments. Center yellowish, border translucent.

Gelatin stab: Thin, iridescent surface growth. Liquefied

Agar slant: Deep orange layer.

Broth: Turbid, with yellowish sediment.

Litmus milk: No coagulation; litmus reduced

Potato: Yellowish layer.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Water.

49. **Flavobacterium fuscum** (Zimmermann) Bergey et al. (*Bacillus fuscus* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, 1890, 70; Bergey et al., Manual, 1st ed., 1923, 113.)

Rods: 0.6 by 1.0 to 1.5 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small with brownish center and yellowish border.

Gelatin stab: Gray, filiform growth in stab. Slow crateriform liquefaction.

Agar colonies: Circular, pale yellow, smooth, slightly convex, entire.

Agar slant: Greenish-yellow, plumose, smooth, raised, undulate.

Broth: Turbid, with pellicle and sediment.
Litmus milk: Slightly acid, becoming alkaline, with yellow ring.
Potato: Thick, moist, chrome-yellow streak.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

50. **Flavobacterium lutescens** (Migula) Bergey et al. (Der gelbe Bacillus, Lustig, Diagnostik der Bakterien des Wassers, 1893, 78; *Bacterium lutescens* Migula, System der Bakterien, 1900, 476; Bergey et al., Manual, 1st ed., 1923, 114.)

Rods: 0.5 by 0.95 micron, occurring singly and in pairs. Non-motile. Gram-negative.
Gelatin colonies: Circular, yellow, lobate.
Gelatin stab: Slow liquefaction.
Agar slant: Pale yellow, becoming golden yellow.
Broth: Turbid.
Litmus milk: Alkaline.
Potato: Luxuriant, golden-yellow growth.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Water.

51. **Flavobacterium esteroaromaticum** (Omelianski) Bergey et al. (*Bacterium esteroaromaticum* Omelianski, Jour. of Bact., *8*, 1923, 407; Bergey et al., Manual, 3rd ed., 1930, 149.)

Rods: 0.5 by 1.0 to 3.0 microns. Non-motile. Gram-negative.
Gelatin stab: Crateriform liquefaction with odor of musk melons.
Agar colonies: Circular, yellow-brown, with fimbriate margin.
Agar slant: Fluorescent layer, with fruity aroma.
Broth: Turbid, slight sediment.
Litmus milk: Peptonized. Cheesy odor.
Potato: Abundant.
Loeffler's blood serum: Liquefied.
Indol not formed.
Nitrates not reduced.
Ammonia formed.
H_2S formed. Fat hydrolyzed.
Methylene blue reduced.
No acid in carbohydrate media.
Aerobic, facultative.
Optimum temperature 37°C.
Accidental contaminant in brain containing rabies virus.

52. **Flavobacterium fecale** Bergey et al. (*Bacillus fecale aromaticum* Stutzer, Cent. f. Bakt., I Abt., Orig. *91*, 1923, 87; Bergey et al., Manual, 3rd ed., 1930, 150.)

Rods: 0.3 to 0.5 by 0.6 to 1.0 micron. Non-motile. Gram-negative.
Gelatin colonies: Circular, flat, conical, yellow, liquefying rapidly.
Gelatin stab: Rapid liquefaction, infundibuliform becoming stratiform.
Agar colony.
Agar slant: Spreading, yellow, glistening, with serrate margin.
Broth: Turbid.
Litmus milk: Peptonized, becoming clear, alkaline.
Potato.
Loeffler's blood serum peptonized.
Indol.
Nitrates.
No acid or gas in carbohydrate media.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal tract.

53. **Flavobacterium helvolum** (Zimmermann) Bergey et al. (*Bacillus helvolus* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, 1890, 52; Bergey et al., Manual, 1st ed., 1923, 114.)

Rods: 0.5 by 1.0 micron, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: Small, circular, yellowish-gray.
Gelatin stab: Napiform liquefaction.
Agar colonies: Circular, pale yellow, smooth, slightly convex.
Agar slant: Pale yellow, plumose to spreading, moist, undulate.
Broth: Turbid, with gray ring and sediment.
Litmus milk: Slightly acid, with soft coagulum, becoming alkaline; peptonized. Litmus reduced.
Potato: Pale green, moist, plumose, becoming rough, dull.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Water.

54. **Flavobacterium deciduosum** (Wright) Bergey et al. (*Bacillus deciduosus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 443; Bergey et al., Manual, 1st ed., 1923, 114.)

Rods: 0.4 by 2.0 microns, with rounded ends, occurring singly and in pairs. Non-motile. Gram-negative.
Gelatin colonies: Small, irregular, yellowish-brown.
Gelatin stab: Slow, fusiform liquefaction.
Agar colonies: Circular, raised, smooth, amorphous, entire, becoming greenish.

Agar slant: Moist, glistening, translucent, brownish-yellow, spreading.
Broth: Turbid, with delicate pellicle.
Litmus milk: Becoming alkaline, peptonized.
Potato: Moist, elevated, rough, brownish-yellow.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

55. **Flavobacterium racemosum** (Zettnow) Bergey et al. (*Bacterium racemosum* Zettnow, Cent. f. Bakt., I Abt., Orig. 77, 1915, 209; Bergey et al., Manual, 1st ed., 1923, 115.)

Filaments: 0.5 to 0.8 by 10 to 12 microns. Branching forms found. Non-motile. Gram-positive.
Gelatin colonies: White, circular, soft, granular, brownish, entire.
Gelatin stab: White surface growth. Liquefaction napiform.
Agar slant: Light yellow, limited.
Broth: Turbid.
Litmus milk: Coagulated, becoming alkaline.
Potato: Dirty-yellowish, limited streak.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 20°C.
Contamination on agar plate.

56. **Flavobacterium fulvum** (Zimmermann) Bergey et al. (*Bacillus fulvus* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, 1890, 44; Bergey et al., Manual, 1st ed., 1923, 115.)

Rods: 0.8 by 0.9 to 1.3 microns, occurring singly, in pairs and in chains. Non-motile. Gram-negative.
Gelatin colonies: Circular, convex, yellowish.
Gelatin stab: Convex, yellowish surface growth. Good growth in stab. Slow liquefaction.
Agar slant: Yellowish, glistening streak.
Broth: Turbid.
Litmus milk: Acid; no coagulation.
Potato: Abundant, yellowish, glistening.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

57. **Flavobacterium dormitator** (Wright) Bergey et al. (*Bacillus dormitator* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 442; Bergey et al., Manual, 1st ed., 1923, 115.)

Rods with conical ends, occurring singly, in pairs and in chains. Non-motile. Gram-negative

Gelatin colonies: Small, yellowish, slightly granular, liquefying.

Gelatin stab: Infundibuliform liquefaction.

Agar slant: Yellowish, glistening, translucent.

Broth: Turbid, with slight pellicle and yellowish sediment.

Litmus milk: Slightly acid; litmus reduced.

Potato: Slight, transparent, yellow growth.

Indol not formed.

Nitrates reduced (trace).

Acid from dextrose, sucrose, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Water.

58. **Flavobacterium polysiphoniae** (Lundestad) Bergey et al. (*Bacterium polysiphoniae* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 331; Bergey et al., Manual, 3rd ed., 1930, 152.)

Rods with rounded ends, 0.5 to 0.6 by 2.0 to 4.0 microns, occurring singly. Non-motile. Gram-negative.

Fish-gelatin colonies: Circular, slightly glistening, transparent, with denser center.

Fish-gelatin stab: Slight, yellowish growth on surface, yellow. Slow, saccate liquefaction.

Sea-weed agar colonies: Circular, flat, with concentric rings, diffuse margin, light yellow. Agar is disintegrated.

Fish-agar slant: Yellow, flat, with undulate margin.

Broth: Turbid with flocculent pellicle and yellowish sediment.

Litmus milk.

Potato.

Indol not formed.

Nitrates not reduced.

No action on carbohydrates.

Slight hydrolysis of starch.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Sea water of Norwegian Coast.

59. **Flavobacterium droebacheuse** (Lundestad) Bergey et al. (*Bacterium droebacheuse* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 329; Bergey et al., Manual, 3rd ed., 1930, 153.)

Rods with rounded ends, 0.5 to 0.6 by 2.0 to 2.6 microns, occurring singly. Non-motile. Gram-negative.

Fish-gelatin colonies: Small, circular, compact, opaque, glistening, orange-yellow.

Fish-gelatin stab: Liquefaction infundibuliform becoming stratiform.

Sea-weed agar colonies: Small, circular, flat, opaque, glistening, orange-yellow. Agar is disintegrated.

Fish-agar slant: Flat, opaque, glistening, slimy, orange-yellow, entire.

Broth: Slight flocculent turbidity, yellow.

Litmus milk.

Potato.

Indol not formed.

Nitrates not reduced.

Starch hydrolyzed.

No action on carbohydrates.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Sea water of Norwegian Coast.

60. **Flavobacterium delesseriae** (Lundestad) Bergey et al. (*Bacterium delesseriae* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 332; Bergey et al., Manual, 3rd ed., 1930, 153.)

Rods with rounded ends, 0.5 to 0.6 by 1.6 to 2.6 microns, occurring singly. Non-motile. Gram-negative.

Fish-gelatin colonies: Circular, transparent, glistening, concentrically ringed, yellow.

Fish-gelatin stab: Crateriform liquefaction, with yellow sediment.

Sea-weed agar colonies: Circular, flat, concentrically ringed, light yellow. Agar is disintegrated.

Fish-agar slant: No growth.

Broth: Turbid with flocculent pellicle and sediment, light yellow.

Litmus milk.

Potato.

Indol not reported.

Nitrates not reported.

No action on carbohydrates.

Slight hydrolysis of starch.

Aerobic, facultative.

Optimum temperature 23°C.

Habitat: Sea water of Norwegian Coast.

61. **Flavobacterium boreale** (Lundestad) Bergey et al. (*Bacterium boreale* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 333; Bergey et al., Manual, 3rd ed., 1930, 154.)

Rods with rounded ends, 0.5 to 0.6 by 1.6 to 2.6 microns, occurring singly. Non-motile. Gram-negative.

Fish-gelatin colonies: Circular, opaque, glistening, concentrically ringed, yellow.

Fish-gelatin stab: Yellow, with crateriform liquefaction.

Sea-water agar colonies: Circular, flat, opaque, glistening, diffuse margin, light yellow. Agar is disintegrated.

Fish-agar slant: Yellow, flat, glistening, opaque, entire.

Broth: Finely flocculent, yellow sediment.

Litmus milk.

Potato.

Indol not reported.

Nitrates not reported.

No action on carbohydrates.

Slight hydrolysis of starch.

Aerobic, facultative.

Optimum temperature 23°C.

Habitat: Sea water of Norwegian Coast.

62. **Flavobacterium ceramicola** (Lundestad) Bergey et al. (*Bacterium ceramicola* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 332; Bergey et al., Manual, 3rd ed., 1930, 154.)

Rods with rounded ends, 0.5 to 0.6 by 1.4 to 2.4 microns, occurring singly and lying side-by-side. Non-motile. Gram-negative.

Fish-gelatin colonies: Circular, glistening, transparent, yellow.

Fish-gelatin stab: Slight, yellow surface growth. Liquefaction crateriform.

Sea-water agar colonies: Circular, flat, transparent, glistening, diffuse margin, light yellow. Agar is disintegrated.

Fish-agar slant: Moderate, yellow, flat, entire, glistening, opaque.

Broth: Light yellow pellicle and sediment.

Litmus milk.

Potato.

Indol not reported.

Nitrates not reported.

No action on carbohydrates.

Slight hydrolysis of starch.

Aerobic, facultative.

Optimum temperature 23°C.

Habitat: Sea water of Norwegian Coast.

63. **Flavobacterium breve** (Frankland and Frankland) Bergey et al. (*Bacillus brevis* G. and P. Frankland, Microorganisms in Water, 1894, 429; Bergey et al., Manual, 1st ed., 1923, 116.)

Rods: 0.8 to 1.0 by 2.5 microns, showing polar staining. Non-motile. Gram-negative.

Gelatin colonies: Minute, pale yellow, compact.

Gelatin stab: Thin, yellowish growth on surface. Beaded growth in stab. No liquefaction.

Agar slant: Yellowish, plumose.

Broth: Turbid with grayish sediment.

Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Water.

64. **Flavobacterium solare** (Lehmann u. Neumann) Bergey et al. (*Bacterium solare* Lehmann and Neumann, Atlas und Grundriss der Bacteriologie, 1896, 258; Bergey et al., Manual, 1st ed., 1923, 116.)

Rods: 0.3 to 0.4 by 1.0 micron, occurring singly, in pairs and in chains. Non-motile. Gram-negative.

Gelatin colonies: Circular, yellow, glistening, translucent.
Gelatin stab: Yellow, arborescent growth in stab. No liquefaction.
Agar colonies.
Agar slant: Pale yellow, raised.
Broth: Clear.
Litmus milk: Unchanged.
Potato: Soft, yellowish-brown streak.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

65. **Flavobacterium ovale** (Wright) Bergey et al. (*Bacillus ovalis* Wright, Memoirs Nat. Acad. Sci., 7, 1895, 435; Bergey et al., Manual, 1st ed., 1923, 117.)

Rods: 0.35 by 2.0 microns, with rounded ends, occurring singly, in pairs and in chains. Non-motile. Gram-negative.

Gelatin colonies: Small, circular, raised, glistening, entire, becoming yellow to brownish in color.

Gelatin stab: Limited, raised, brownish-yellow surface growth. No liquefaction.

Agar colonies: Circular, raised, smooth, amorphous, entire, yellowish-green.

Agar slant: Thick, pale yellow, glistening.
Broth: Clear, with grayish sediment.
Litmus milk: Reaction unchanged. Litmus reduced.
Potato: Brownish-yellow, moist, spreading, viscid.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

66. **Flavobacterium flavotennae** Schrire. (Trans. Royal Soc. South Africa, *17*, 1928, 45.)

Small rods: Non-motile. Gram-negative.

Gelatin colonies.

Gelatin stab.

Agar colonies: Small, circular, lemon yellow, raised, entire.

Agar slant: Filiform, lemon yellow.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Moist, yellow streak.

Indol not formed.

Nitrates are reduced.

Acid in dextrose, galactose and xylose.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Associated with wound infection in frogs.

67. **Flavobacterium lacunatum** (Wright) Bergey et al. (*Bacillus lacunatus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 435; Bergey et al., Manual, 1st ed., 1923, 117.)

Small rods, short, with rounded ends, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Thin, translucent with grayish center, becoming yellowish, serrate.

Gelatin stab: Grayish, translucent surface growth, with yellowish center. No liquefaction.

Broth: Turbid.

Litmus milk: Acid; becoming brownish.

Potato: Thin, viscid, becoming brownish.

Indol is formed.

Nitrates not reduced

Aerobic, facultative.

Optimum temperature 30°C

Habitat: Water.

68. **Flavobacterium salmonicolor** (den Dooren de Jong) Bergey et al. (*Mycobacterium salmonicolor* den Dooren de Jong, Cent. f. Bakt., II Abt., *71*, 1927, 216; Bergey et al., Manual, 3rd ed., 1930, 157.)

Rods: Non-motile. Gram positive.

Agar colonies: Circular, lilac colored.

Amino agar colonies: Circular, orange yellow.

Disintegrates the following organic acids: Acetic, a-crotonic, glycolic, lactic, *b*-oxybutyric, glycerinic, malonic, formic, methyl-formic, glutaric, adipic, maleinic, fumaric, malic, tartaric, citric, *b*-phenylpropionic and chinic.

Disintegrates the following amino compounds: Sarcosin, betain, hippuric acid, phenylalanin, tyrosin, *d*-aminovalerianic acid, *a*-amino-capronic

acid, leucin, asparaginic acid, propionamid, carpronamid, lactamid, succinamid, asparagin, creatin, allantoin.

Disintegrates the following amine compounds: Ethylamin, propylamin, butylamin, iso-butylamin, amylamin, ethanolamin, pentamethylen-diamin, benzylamin, histamin.

Attacks dextrose and ethyl alcohol

Aerobic: facultative.

Optimum temperature 25°-30°C.

Habitat: Soil.

Genus III. Chromobacterium *Bergonzini, 1881.*

Aerobic bacteria producing a violet, chromoparous pigment, soluble in alcohol but not in chloroform.

The type species is *Chromobacterium violaceum* (Schroeter) Bergonzini.

Key to the species of genus Chromobacterium.

I. Motile rods. Flagella peritrichous
  1. Gelatin liquefied
    a. Milk alkaline; peptonized.
    b. Nitrates not reduced.
    c. Indol not formed.
      1. *Chromobacterium violaceum.*
      2. *Chromobacterium lividum.*
      3. *Chromobacterium bamptonii.*
      4. *Chromobacterium membranaceum.*

II Motile rods. Flagella polar
  1. Gelatin liquefied.
    a. Milk coagulated
    b. Nitrates not reduced
    c. Indol is formed.
      5. *Chromobacterium ianthinum.*
      6. *Chromobacterium coeruleum.*
      7. *Chromobacterium smithii.*

III. Non-motile rods.
  1. Gelatin liquefied.
    a. Milk alkaline; digested
    b. Nitrates not reduced.
    c. Indol not formed.
      8. *Chromobacterium amethystinum*
      9. *Chromobacterium viscosum.*
    aa. Milk becoming acid; coagulated; peptonized.
    b. Nitrates not reduced.
    c. Idol not formed.
      10. *Chromobacterium visco-fucatum.*

1. **Chromobacterium violaceum** (Schroeter) Bergonzini. (*Bacteridium violaceum* Schroeter, Cohn's Beitrage z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 126; *Micrococcus violaceus* Cohn, Beitrage z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 157; *Cromobacterium violaceus* Bergonzini, Ann. Società d. Naturalisti in Modena, Ser. 2, *14*, 1881, 153; *Bacillus violaceus* Schroeter, Kryptogamen Flora von Schlesien, *3*, 1886, 157; *Bacterium violaceum* Lehmann and Neumann, Atlas u. Grundiss d. Bakteriologie, 1898 (See Eng. Transl. 1901, 277); *Pseudomonas violaceus* Migula, Engler and Prantl. Die Natürlichen Pflanzenfamilien, *1*, 1a, 1895, 29.)

Note: *Bacterium ianthinum* Zopf (Die Spaltpilze, 1885, 68) has been regarded as identical with the above organism by Schroeter (Kryptogamen-Flora von Schlesien, *3*, 1, 1886, 157), and by Lehmann and Neumann (Atlas u. Grundriss d. Bakteriologie, 1896, 266, also 1927, 463). Lehmann and Neumann (loc. cit.) also consider *Bacillus violaceus laurenticus* Lustig (Diagnostik der Bakterien des Wassers, 1893, 103) as being identical with *Bacterium violaceum.*

Slender rods: 0.8 to 1.0 by 2.0 to 5.0 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, gray, entire margin, assuming a violet color in the center.

Gelatin stab: Infundibuliform liquefaction with violet sediment in fluid.

Agar colonies: Whitish, flat, glistening, moist, becoming violet.

Agar slant: Deep, violet, spreading growth.

Broth: Slightly turbid, with violet ring and ropy sediment.

Litmus milk: Violet pellicle. Digestion. Alkaline.

Potato: Limited, dark violet growth.

Loffler's blood serum is slowly liquefied.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Water.

2. **Chromobacterium lividum** (Voges) Holland. (Plagge and Proskauer, Zeitsch. f. Hyg., *2*, 1887, 463; *Bacillus lividus* Voges, Cent. f. Bakt., *14*, 1893, 303; Relationship to *Bacillus lividus* Zimmermann uncertain. Die Bakt. unserer Trink- und Nutzwässer, Chemnitz, 1890, 18; Holland, Jour. Bact., *5*, 1920, 215.)

Slender rods, occurring singly. Motile by means of peritrichous flagella, Gram-negative.

Gelatin colonies: Black, like drops of ink.

Gelatin stab: Violet surface growth. Slow liquefaction.

Agar slant: Blue-black growth.

Broth: Turbid.

Litmus milk: Alkaline; digested.

Potato: Violet growth.

Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Water.

3. **Chromobacterium bamptonii** Bergey et al. (*Bacillus membranaceus amethystinus II* Bampton, Cent. f. Bakt., I Abt., Orig. *71*, 1913, 129; Bergey et al., Manual, 1st ed., 1923, 119.)

Rods: 1.4 to 3.5 microns long, with rounded ends. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Pale, bluish, sinking into medium, becoming deep violet.

Gelatin stab: Pale violet surface growth, becoming deep violet. Liquefied with brownish flocculi in liquid.

Agar colonies: Pale violet.
Agar slant: Grayish-white layer, becoming violet.
Broth: Turbid, with violet pellicle.
Litmus milk: Alkaline; peptonized.
Potato: Yellowish-brown, granular membrane.
Blood serum: Whitish-violet membrane; no peptonization.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, maltose and sucrose.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

4. **Chromobacterium membranaceum** Bergey et al. (*Bacillus membranaceus amethystinus I* Bampton, Cent. f. Bakt., I Abt., Orig. *71*, 1913, 135; Bergey et al., Manual, 1st ed., 1923, 119.)

Rods: 1.4 to 3.5 microns long, occurring singly and in short chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Bluish-white, slightly convex, undulate, slightly granular.

Gelatin stab: Whitish surface growth, spreading, becoming violet. Slow infundibuliform liquefaction.

Agar colonies: Small, circular, convex, yellowish-white, moist, becoming pale violet.

Agar slant: Whitish, membranous, becoming pale yellow with violet center.

Broth: Turbid, with pale violet pellicle and whitish sediment.
Litmus milk: Alkaline; peptonized.
Potato: Brownish to pale violet, membranous, granular.
Blood serum: Slowly peptonized
Indol not formed.
Nitrates not reduced.

Acid in dextrose and maltose.
Aerobic, facultative.
Optimum temperature 37.5°C.
Habitat: Water.

5. **Chromobacterium ianthinum** (Zopf) Holland. (*Bacterium ianthinum* Zopf, Die Spaltpilze, 1884, 62; *Bacillus janthinus* Flügge, die Mikroorganismen 1886, 291; *Bacteridium ianthinum* Schroeter, Kryptogamen Flora von Schlesien, 1886, 157; *Pseudomonas ianthina* Migula, System der Bakterien, 1900, 941; Holland, Jour. Bact., *5*, 1920, 222.)

Rods: 0.5 to 0.8 by 1.5 to 5.0 microns, occurring singly. Motile with one or two polar flagella. Gram-negative.
Gelatin colonies: Circular, yellow, becoming violet.
Gelatin stab: White to violet surface growth. Infundibuliform liquefaction.
Agar slant: Yellowish, moist, glistening, becoming deep violet.
Broth: Turbid, with light violet pellicle.
Litmus milk: Slow coagulation with violet cream layer.
Potato: Violet to violet-black, spreading growth.
Forms H_2S.
Indol is formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C. Grows well at 37°C.
Habitat: Water and soil.

6. **Chromobacterium coeruleum** (Voges) Bergey et al. (*Bacillus coeruleus* Voges, Cent. f. Bakt., *14*, 1893, 301; *Pseudomonas coerulea* Chester, Determinative Bacteriology, 1901, 318; Bergey et al., Manual, 1st ed., 1923, 120.)

Rods: 0.8 by 1.0 to 1.4 microns, occurring singly. Motile by polar flagella. Gram-negative.
Gelatin colonies: Bluish-gray.
Gelatin stab: Slight surface growth. Slow infundibuliform liquefaction.
Agar slant: Bluish-gray, moist, glistening.
Broth: Grayish pellicle.
Litmus milk: Coagulated with sky-blue cream layer.
Potato: Grayish blue to blue-green growth, darkening with age.
Indol is formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C. Grows well at 37°C.
Habitat: Water.

7. **Chromobacterium smithii** (Chester) Bergey et al. (*Bacillus coeruleus* Smith, Medical News, 1887, 758; *Pseudomonas smithii* Chester, Determinative Bacteriology, 1901, 318; Bergey et al., Manual, 1st ed., 1923, 121.)

Rods: 0.5 by 2.0 to 2.5 microns, occurring singly and in chains. Motile with polar flagella. Gram-negative.

Gelatin colonies: Faint, blue.

Gelatin stab: Infundibuliform liquefaction.

Agar slant: Faint bluish growth.

Broth: Turbid, with blue ring.

Litmus milk: Coagulated with blue whey. Reduction.

Potato: Blue to dirty-brown growth, turning black.

Indol is formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30°C. Grows well at 37°C.

Habitat: Water.

8. **Chromobacterium amethystinum** Holland. (*Bacillus membranaceus amethystinus* Eisenberg, Bakt. Diagnostik, 1891, 421; Holland, Jour. Bact. *5*, 1920, 215.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Thin, bluish, becoming violet, crumpled.

Gelatin stab: Yellowish-white surface growth. Liquefied.

Agar slant: Thick, moist, yellowish-white, becoming violet with metallic luster.

Broth: Pellicle with violet sediment. Fluid becoming brownish.

Litmus milk: Violet pellicle. Digestion. Alkaline.

Potato: Slowly-developing greenish-white to olive-green growth.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Water.

9. **Chromobacterium viscosum** Grimes. (Cent. f. Bakt., II Abt., *72*, 1927, 367.)

Rods: 0.4 to 0.6 by 0.5 to 1.0 microns, occurring singly, in pairs, and short chains. Non-motile. Gram-positive.

Gelatin colonies: Circular, dirty grayish, raised, glistening, opaque, entire.

Gelatin stab: Greenish-yellow, slow stratiform liquefaction.

Agar colonies: Circular, grayish, raised, smooth, glistening, finely granular, entire.

Agar slant: Abundant, grayish-white, spreading, opaque, viscous.

Broth: Turbid with gray sediment.

Litmus milk: Alkaline. Peptonized.

Potato: Moderate, blue streak.

Indol not formed.

Nitrates not reduced.

Starch hydrolyzed.
No gas in carbohydrate media.
Violet pigment formed in media containing sugars.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Butter and cream.

10. **Chromobacterium visco-fucatum** (Harrison and Barlow) Bergey et al. (*Bacterium visco-fucatum* Harrison and Barlow, Cent. f. Bakt., II Abt., *15*, 1905, 517; Trans. of the Royal Soc. of Canada, 2nd Ser., *11*, 1905; Bergey et al., Manual, 1st ed., 1923, 121.)

Rods: 0.6 to 0.9 by 1.0 to 1.8 microns, occurring singly, in pairs and in short chains. The rods are straight or slightly bent, of even thickness but frequently tapering at one or both ends. Encapsulated. Non-motile. Gram-negative.

Gelatin colonies: Small, yellow green, with colorless crystals in the medium. On adding dextrose, maltose, sucrose or mannitol to the gelatin blue or violet pigment is formed. On adding galactose, dextrin and starch to the gelatin green pigment is formed. Pigment grains are demonstrable in the colonies and surrounding medium.

Gelatin stab: Slight, crateriform liquefaction.

Agar colonies: Small, circular, raised, moist, glistening, white, entire, becoming yellowish, opaque.

Agar slant: Slow, filiform growth.

Sucrose agar slant: Abundant growth, with faint blue pigment.

Broth: Turbid with ropy sediment, with slight green-blue pigment in six days.

Litmus milk: Becoming gray-blue or green-blue in color from above downward. Slowly peptonized. A soft curd is formed in 20 days, becoming distinctly acid.

Potato: Yellowish white, raised, moist, glistening, slimy, entire, spreading, becoming green-blue to bright blue and later assuming an amber color.

Loffler's blood serum: Raised, smooth, glistening, yellowish-white in color. No liquefaction.

Indol not formed.
Nitrates not reduced.
No gas in carbohydrate media.
Aerobic, facultative.
Optimum temperature 18 to 22°C.
Habitat: Isolated from oily butter.

Genus IV. Pseudomonas *Migula, 1894.*

Principally water and soil bacteria producng a water-soluble pigment which diffuses through the medium as green, blue or yellowish-green. Motile or non-motile. Gram-negative.

The type species is *Pseudomonas aeruginosa* (Schroeter) Migula.

Key to the species of genus **Pseudomonas.**

1. Motile rods. Flagella polar.
   - A. Gelatin liquefied.
     - a. Milk coagulated; peptonized.
     - b. Nitrates reduced.
     - c. Indol is formed.
       - 1. *Pseudomonas aeruginosa.*
       - 2. *Pseudomonas myxogenes.*
     - cc. Indol not formed.
       - 3. *Pseudomonas chlororaphis.*
     - bb. Nitrates not reduced.
     - c. Indol is formed.
       - 4. *Pseudomonas capsulata.*
       - 5. *Pseudomonas schuylkiliensis.*
       - 6. *Pseudomonas centrifugans.*
       - 7. *Pseudomonas dermatogenes.*
     - aa. Milk not coagulated.
     - b. Nitrates reduced.
     - c. Indol not formed.
       - 8. *Pseudomonas fluorescens.*
       - 9. *Pseudomonas boreopolis.*
     - aaa. Milk unchanged.
     - b. Nitrates not reduced.
     - c. Indol not formed.
       - 10. *Pseudomonas syncyanea.*
     - aaaa Milk alkaline
       - 11. *Pseudomonas septica.*
       - 12. *Pseudomonas calciprecipitans.*
   - B. Gelatin not liquefied.
     - a. Milk coagulated.
     - b. Nitrates not reduced.
     - c. Indol is formed.
       - 13. *Pseudomonas rugosa.*
     - aa. Milk not coagulated.
     - b. Nitrates reduced.
     - c. Indol is formed.
       - 14. *Pseudomonas striata.*
     - cc. Indol not formed.
       - 15. *Pseudomonas incognita.*
       - 16. *Pseudomonas putida.*
     - bb. Nitrates not reduced.
     - c. Indol not formed.
       - 17. *Pseudomonas ovalis.*
       - 18. *Pseudomonas convexa.*
       - 19. *Pseudomonas mildenbergii.*

2. Motile rods. Flagella peritrichous.
    A. Gelatin liquefied.
        a. Milk not coagulated.
        b. Nitrates not reduced.
        c. Indol not formed.
            20. *Pseudomonas viscosa.*
            21. *Pseudomonas jaegeri.*
        aa. Milk peptonized.
        b. Nitrates reduced.
            22. *Pseudomonas ureae.*
    B. Gelatin not liquefied.
        a. Milk not coagulated.
        b. Nitrates reduced.
        c. Indol not formed.
            23. *Pseudomonas scissa.*
            24. *Pseudomonas denitrificans.*
3. Motile. Flagellation not reported.
    A. Gelatin liquefied.
        a. Starch hydrolyzed.
            25. *Pseudomonas gelatica.*
        aa. Starch not hydrolyzed.
            26. *Pseudomonas pavonacea.*
    B. Gelatin not liquefied.
            27. *Pseudomonas pierantonii.*
4. Non-motile rods.
    A. Gelatin liquefied.
        a. Milk not coagulated.
        b. Nitrates not reduced.
        c. Indol not formed.
            28. *Pseudomonas smaragdina*
        bb. Nitrates reduced.
        c. Indol formed.
            29. *Pseudomonas chlorina.*
    B. Gelatin not liquefied.
        a. Milk unchanged.
        b. Nitrates not reduced.
        c. Indol not formed.
        d. Phosphorescence absent.
            30. *Pseudomonas non-liquefaciens.*
        dd. Phosphorescent.
            31. *Pseudomonas phosphorescens.*

1. **Pseudomonas aeruginosa** (Schroeter) Migula. (*Bacterium aeruginosum* Schroeter, Cohn's Beiträge z. Biologie, *1*, Heft 2, 1872, 126; *Bacillus pyocyaneus* Gessard, Compt. rend., Acad. d. Sci., Paris, *94*, 1882, 536; *Pseudomonas pyocyanea* Migula, Engler and Prantl, Die Natürlichen

Pflanzenfamilien, *1*, 1a, 1895, 29; *Bacterium pyocyaneum* Lehmann u. Neumann, Atlas u. Grundriss der Bakteriologie, 1896, 267; Migula, System der Bakterian, 1900, 884.)

Rods: 0.5 to 0.6 by 1.5 microns, occurring singly, in pairs and short chains. Motile, possessing one to three polar flagella. Gram-negative.

Gelatin colonies: Yellowish or greenish-yellow, fringed, irregular, skein-like, granular, rapidly liquefying.

Gelatin stab: Rapid liquefaction. The fluid assuming a yellowish-green or bluish-green color.

Agar colonies: Large, spreading, grayish with dark center and translucent edge, irregular. The medium assumes greenish color.

Agar slant: Abundant, thin, white, glistening, the medium turning green to dark brown or black, fluorescent.

Broth: Marked turbidity with thick pellicle and heavy sediment, the medium becoming yellowish-green to blue, with fluorescence, later brownish.

Litmus milk: A soft coagulum is formed, with rapid peptonization and reduction of litmus. Reaction alkaline.

Potato: Luxuriant, dirty-brown, the medium becoming dark green.

Indol is formed.

Nitrates are reduced to nitrites and nitrogen.

Dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, dextrin, inulin, glycerol, mannitol and dulcitol are not attacked.

Blood serum: Liquefied. Yellow liquid, greenish on surface.

Blood hemolyzed.

Cultures have marked odor of trimethylamine.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Open wounds; old sinuses. Intestinal canal; sewage. Pathogenic for rabbits, guinea pigs, rats and mice.

2. **Pseudomonas myxogenes** Fuhrmann. (Cent. f. Bakt. II Abt., *17*, 1907, 356.)

Rods: 0.4 to 0.5 by 1.0 to 1.5 microns, occurring singly and in pairs. Motile, possessing a bundle of five to seven polar flagella. Gram-negative.

Gelatin colonies: Smooth, soft, flat, spreading, entire, yellowish-green.

Gelatin stab: Growth along stab. Liquefaction with yellowish-white sediment.

Agar colonies: Circular, raised, smooth, amorphous, entire.

Agar slant: Yellowish-white, moist, glistening, becoming light green-fluorescent.

Broth: Turbid, with yellowish-white sediment.

Litmus milk: Flocculent precipitation. Slow peptonization with yellow serum. Alkaline.

Potato: Dirty yellow to olive, moist, glistening, entire.

Indol is formed.

Nitrates reduced to nitrites and ammonia. No gas formed.
Aerobic, facultative.
Optimum temperature 22°C.
Habitat: Isolated from beer.

3. **Pseudomonas chlororaphis** (Guignard and Sauvageau) Bergey et al. (*Bacillus chlororaphis* Guignard and Sauvageau, C. R. Soc. de Biol., *1*, 10 sér., 1894, 841; Bergey et al., Manual, 3rd ed., 1930, 166.)

Rods: 0.8 by 1.5 microns, with rounded ends, occurring singly and in pairs. Motile with polar flagella. Gram-negative.

Gelatin colonies: Circular, viscid, transparent, glistening, lobate margin, with fluorescent corona.

Gelatin stab: Stratiform liquefaction.

Agar colonies.

Agar slant.

Broth: Turbid, fluorescent, with crystals of chlororaphine.

Litmus milk: Coagulation. Peptonization. Crystals of chlororaphine form in the central part of the culture.

Potato: Citron-yellow layer. Crystals of chlororaphine are formed.

Indol not formed.

Nitrates reduced to nitrites.

Pigment formation: Asparagin, potassium phosphate, glycerol, sulphate of magnesium and sulphate of iron are indispensable to the formation of crystals of chlororaphine.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Pathogenic for laboratory animals. Exotoxin formed.

Habitat: Water.

4. **Pseudomonas capsulata** Bergey et al. (*Bacillus fluorescens capsulatus* Pottien, Zeitschr. f. Hyg., *11*, 1896, 140; Bergey et al., Manual, 1st ed. 1923, 124.)

Small rods with rounded ends, occurring singly and in pairs. Motile, possessing a polar flagellum. Gram-negative. Encapsulated.

Gelatin colonies: Brownish, granular with greenish-shimmer.

Gelatin stab: Liquefaction infundibuliform. The liquefied medium takes on a yellowish-green color.

Agar slant: Moist, glistening, with bluish shimmer and grayish-green fluorescence.

Broth: Turbid, with thick pellicle and green fluorescence.

Litmus milk: Coagulation with green fluorescence at surface; peptonized.

Potato: Slimy, grayish-green to yellowish-brown layer.

Indol is formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from intestinal contents in cholera nostras.

5. **Pseudomonas schuylkilliensis** Chester. (*Bacillus fluorescens schuylkilliensis* Wright, Memoirs, Natl. Acad. Sci., *7*, 1895, 448; Chester, Determinative Bact., 1901, 320.)

Short rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum Gram-negative.

Gelatin colonies: Grayish-white, translucent, with brownish center, radiate margin, becoming bluish-green.

Gelatin stab: Slow crateriform liquefaction, with blue-green fluorescence.

Agar slant: Grayish, translucent growth. Medium shows greenish fluorescence.

Broth: Turbid, with slight pellicle and blue-green fluorescence.

Litmus milk: Coagulated, with slow reduction of litmus; peptonized.

Potato: Brownish, raised, spreading.

Indol is formed (trace).

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Water.

6. **Pseudomonas centrifugans** (Wright) Chester. (*Bacillus centrifugans* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 462; Chester, Determinative Bact., 1901, 312.)

Medium-sized rods, occurring singly, in pairs and in chains. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, with fimbriate margin, grayish, translucent.

Gelatin stab: Saccate liquefaction.

Agar slant: Thin, grayish, translucent, becoming brownish to greenish brown.

Broth: Turbid, with pellicle, becoming brownish-green.

Litmus milk: Slightly acid; coagulated; peptonized. Litmus reduced.

Potato: Thick, spreading, grayish-pink, with rough, granular surface.

Indol is formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Water.

7. **Pseudomonas dermatogenes** Fuhrmann. (Cent. f. Bakt. II Abt., *17*, 1907, 356.)

Rods: 0.7 by 1.2 to 1.3 microns, occurring singly and in pairs. Motile, possessing three to five polar flagella. Gram-negative.

Gelatin colonies: Small, entire, yellowish-brown.

Gelatin stab: Growth along stab. Liquefaction infundibuliform.

Agar slant: Soft, moist, finely granular, light yellow. The medium shows green fluorescence.

Broth: Turbid, becoming yellow, with grayish-white sediment.

Litmus milk: Slow coagulation, whey turning yellowish-green.

Potato: Light, yellowish-brown, smooth, glistening.
Indol is formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Isolated from beer.

8. **Pseudomonas fluorescens** Migula. (*Bacillus fluorescens liquefaciens* Flügge, Die Mikroorganismen, 1886, 289; Migula, Engler and Prantl, Die Natürlichen Pflanzenfamilien, *1*, 1a, 1895, 29; *Bacterium fluorescens* Lehmann u. Neumann, Atlas u. Grundriss der Bacteriologie, 1896, 272.)

Rods: 0.3 to 0.5 by 1.0 to 1.8 microns, occurring singly and in pairs. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Circular, with greenish center, lobular, liquefying quickly.

Gelatin stab: Infundibuliform liquefaction, with whitish to reddish gray sediment.

Agar slant: Abundant, reddish layer, becoming reddish-gray. The medium shows greenish to olive-brown coloration.

Broth: Turbid, flocculent, with yellowish-green pellicle and grayish sediment.

Litmus milk: No coagulation; becoming alkaline.

Potato: Thick, grayish-yellow, spreading, becoming light sepia-brown in color.

Indol is not formed.
Nitrates reduced to nitrites and ammonia.
Acid in dextrose.
Blood serum liquefied.
Aerobic.
Optimum temperature 20° to 25°C.
Not pathogenic.
Habitat: Soil and water.

9. **Pseudomonas boreopolis** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 74.)

Rods: 0.5 to 1.0 by 2.0 to 3.0 microns, occurring singly and in pairs Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Liquefied.

Gelatin stab: Liquefied. Medium reddened.

Agar colonies: Circular or amoeboid, white to buff, flat to convex, smooth, glistening, translucent border.

Agar slant: Filiform, whitish, raised, smooth, glistening, fluorescent.
Broth: Turbid.
Litmus milk.
Potato.
Indol.
Nitrates reduced to nitrites.

Starch not hydrolyzed.
Acid produced from dextrose
Attacks naphthalene.
Aerobic, facultative.
Optimum temperature
Habitat: Soil.

10. **Pseudomonas syncyanea** (Ehrenberg) Migula. (*Vibrio syncyaneus* Ehrenberg, Bericht über die Verhandlungen der Berliner Akademie, 1840, 202; *Vibrio cyanogenes* Fuchs, Magazin für die gesamte Tierheilkunde, *7*, 1841, 190; *Bacillus syncyaneus* Schroeter, Kryptog. Flora v. Schlesien, *3*, 1, 1886, 157; *Bacillus cyanogenes* Flügge, Die Mikroorganismen, 1886, 291; Migula, Engler and Prantl, Die Natürlichen Pflanzenfamilien, *1*, 1a, 1895, 29; *Bacterium syncyaneum*, Lehmann and Neumann, Atlas u. Grundriss d. Bakteriologie, 1896, 275.)

Rods with rounded ends, occurring singly, occasionally in chains, 0.7 by 2.0 to 4.0 microns. Motile with two to four polar flagella. Gram-negative.

Gelatin colonies: Flat, bluish, translucent.

Gelatin stab: Surface growth shiny, grayish blue. The medium is colored steel-blue with greenish fluorescence. Gelatin is liquefied.

Agar slant: Grayish-white streak. The medium takes on a bluish-gray color with slight fluorescence.

Broth: Turbid with marked fluorescence.

Litmus milk: Unchanged. In association with lactic acid bacteria the milk takes on a deep blue color.

Potato: Yellowish-gray, shiny layer, becoming bluish-gray. The medium becomes bluish-gray.

Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: The cause of "blue milk."

11. **Pseudomonas septica** Bergey et al. (*Bacillus fluorescens septicus* Stutzer and Wsorow, Cent. f. Bakt., II Abt., *71*, 1927, 113; Bergey et al., Manual, 3rd ed., 1930, 169.)

Rods: 0.6 to 0.8 by 0.8 to 2.0 microns, occurring singly. Motile with a polar flagellum. Gram-negative.

Gelatin colonies.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Circular with opalescent center and transparent periphery.

Agar slant: Moderate, undulate margin.

Broth: Turbid with fragile pellicle, greenish in upper portion.

Litmus milk: Alkaline, coagulated.

Potato.

Indol.
Nitrates.
Blood serum not liquefied.
Acid in dextrose.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Disease of caterpillars.

12. **Pseudomonas calciprecipitans** Molisch (Cent. f. Bakt., II Abt., *65*, 1925, 130.)

Thin rods: 0.5 to 0.8 by 1.5 to 3.6 microns, with rounded ends, often staining irregularly. Motile, with one polar flagellum. Gram-negative.

Gelatin colonies: Circular, light brown in color. (Large colonies show $CaCO_3$ crystals.)

Gelatin stab: Surface growth with filiform growth in depth. Liquefaction starts at bottom.

Agar colonies (sea water). Grayish-white, glistening. In two to three weeks crystals of calcium carbonate form in the agar.

Agar slant: Slight, whitish, surface growth, becoming thick, spreading, glistening, with abundant $CaCO_3$ crystals in medium.

Ammonia formed.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Sea water.

13. **Pseudomonas rugosa** (Wright) Chester. (*Bacillus rugosus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 438; not *Bacillus rugosus* Chester, Determinative Bacteriology, 1901, 220; Chester, Determinative Bacteriology, 1901, 323.)

Small rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing one to four polar flagella. Gram-negative.

Gelatin colonies: Grayish, translucent, slightly raised, irregular, sinuous, radiately erose to entire.

Gelatin stab: Dense grayish-green, limited, wrinkled, reticulate surface growth. No liquefaction.

Agar slant: Grayish-white, limited, slightly wrinkled, translucent.
Broth: Turbid, with grayish pellicle and sediment.
Litmus milk: Acid; coagulated.
Potato: Moist, glistening, brown.
Indol is formed.
Nitrates not reduced.
Aerobic.
Optimum temperature 30°C.
Habitat: Water.

14. **Pseudomonas striata** Chester. (*Bacillus striatus viridis* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 22; Chester, Determinative Bacteriology, 1901, 325.)

Slender rods, of variable lengths, staining irregularly, occurring singly and in pairs. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, yellowish, with filamentous border.

Gelatin stab: Raised, white, surface growth. No liquefaction.

Agar slant: Thin, yellowish-green, smooth, glistening.

Broth: Turbid, becoming slightly greenish.

Litmus milk: No coagulation; becoming alkaline; litmus reduced.

Potato: Moist, glistening, becoming chocolate-brown.

Indol is formed.

Nitrates are reduced.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

15. **Pseudomonas incognita** Chester. (*Bacillus fluorescens incognitus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 436; Chester, Determinative Bateriology, 1901, 323.)

Short rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Thin, transparent, slightly granular, becoming greenish. Margin undulate. The medium assumes a blue-green fluorescence.

Gelatin stab: No liquefaction.

Agar slant: Thin, moist, translucent, becoming greenish.

Broth: Turbid, with pellicle, becoming greenish.

Litmus milk: Slightly acid in a month. The litmus is slowly reduced.

Potato: Moist, glistening, spreading, brown.

Indol is formed (trace).

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Water.

16. **Pseudomonas putida** Migula. (*Bacillus fluorescens putidus* Flügge, Die Mikroorganismen, 1886, 288; Migula, Engler and Prantl, Die Natürlichen Pflanzenfamilien, *1*, 1a, 1895, 29.)

Rods, with rounded ends. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Small, finely granular, with dark center, surrounded by a yellow zone, with pale gray margin.

Gelatin stab: Dirty-white surface growth, becoming greenish, fluorescent. No liquefaction.

Agar colonies: Circular, raised, smooth, amorphous, entire, with fluorescent zone around the periphery.

Agar slant: Yellowish-green layer, becoming fluorescent.

Broth: Turbid, fluorescent.

Litmus milk: Unchanged.

Potato: Thin, gray to brownish, slimy layer.

Cultures give off odor of trimethylamine.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Putrefying materials; water.

17. **Pseudomonas ovalis** Chester. (*Bacillus fluorescens ovalis* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 9; Chester, Determinative Bacteriology, 1901, 325; Not *Bacillus ovalis* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 435.)

Rods: 0.3 to 0.7 by 0.7 to 1.3 microns, occurring singly. Motile, possessing a single polar flagellum. Gram-negative.
Gelatin colonies: Irregular, lobate, slightly granular.
Gelatin stab: No liquefaction.
Agar colonies: Circular, opaque, entire, greenish fluorescence.
Agar slant: Thick, white, becoming greenish, fluorescent.
Broth: Turbid, with pellicle.
Litmus milk: No coagulation; alkaline.
Potato: Luxuriant, dirty-brown.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Blood serum not liquefied.
Acid in dextrose.
Aerobic, facultative
Optimum temperature 25°C.
Habitat: Soil. Has been found in intestinal canal.

18. **Pseudomonas convexa** Chester. (*Bacillus fluorescens convexus* Wright, Memoirs Nat. Acad. Sci., *7*, 1895, 438; Chester, Determinative Bacteriology, 1901, 325.)

Short, thick rods, with rounded ends. Motile, possessing a polar flagellum. Gram-negative.
Gelatin colonies: Circular, convex, glistening, bright greenish, translucent. The medium becomes blue-green, fluorescent.
Gelatin stab: Light green, raised, glistening surface growth. No liquefaction.
Agar slant: Moist, translucent, glistening, light greenish. The medium assumes a greenish color.
Broth: Turbid, becoming greenish.
Litmus milk: No coagulation; alkaline.
Potato: Pale brown, spreading.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Water.

19. **Pseudomonas mildenbergii** Bergey et al. (Der blaue bacillus, Mildenberg, Cent. f. Bakt., II Abt., *56*, 1922, 309; *Pseudomonas cyanogena* Bergey et al., Manual, 1st ed., 1923, 129; not *Bacillus cyanogenes* Flügge, 1886, 201; Bergey et al., Manual, 3rd ed., 1930, 172.)

Rods: 0.3 to 0.5 by 1.0 to 3.5 microns, with rounded ends, occurring singly. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, lobed, smooth, glistening, slightly raised, steel-blue, entire.

Gelatin stab: No liquefaction.

Agar colonies: Small, circular, yellowish or reddish-yellow, entire, becoming lobed, grayish-green, iridescent. The medium becomes dirty, grayish green.

Agar slant: Smooth, spreading, slimy, glistening, grayish-green to dark green, fluorescent.

Broth: Turbid green, iridescent to opalescent with slimy sediment.

Litmus milk: Not coagulated, blue ring.

Potato: Slimy, glistening, spreading, steel blue.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Isolated from air.

20. **Pseudomonas viscosa** (Frankland and Frankland) Migula. (*Bacillus viscosus* G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 391; Migula, System der Bakterien, 1900, 900.)

Small rods: 0.5 by 1.5 to 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish, granular, with fimbriate margin. Medium assumes a grayish color.

Gelatin stab: Infundibuliform liquefaction, with greenish-white pellicle.

Agar slant: Thin, greenish-white, the medium becoming greenish.

Broth: Turbid, with greenish pellicle.

Litmus milk: Not coagulated.

Potato: Moist, chocolate-brown, viscid.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Water.

21. **Pseudomonas jaegeri** Migula. (*Bacillus proteus fluorescens* Jaeger, Zeitschr. f. Hyg., *12*, 1892 593; Migula, System der Bakterien, 1900, 885.)

Short, thick rods, with rounded ends, occurring singly and in pairs. Flagella peritrichous. Gram-negative.

Gelatin colonies: Small, transparent, becoming proteus-like.

Gelatin stab: Marked surface growth. Saccate to infundibuliform liquefaction.

Agar slant: Thick, yellowish-white layer, the medium becoming greenish-fluorescent. At times gas is formed.

Broth: Turbid, with greenish-gray pellicle and sediment.

Litmus milk: Not coagulated.

Potato: Thick, dark brown layer, slimy. The medium becomes bluish-green.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Water. Found by Jaeger in Weil's disease (Infectious jaundice). Pathogenic for chickens.

22. **Pseudomonas ureae** Bergey et al. (Culture No. 3 of Rubentschick, Cent. f. Bakt., II Abt., *72*, 1927, 101; Bergey et al., Manual, 3rd ed., 1930, 173.)

Rods: 0.6 to 0.7 by 1.7 to 2.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Gram-positive.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Circular, grayish-white.

Agar slant: Grayish-white layer becoming greenish-fluorescent.

Broth: Turbid.

Litmus milk: Peptonized.

Potato: Yellowish-brown streak.

Indol not formed.

Nitrates reduced with gas formation.

Urea attacked.

H_2S formed.

Ammonia formed.

Methylene blue reduced.

Aerobic, facultative.

Can grow at 0°C.

Optimum temperature 20°C.

Habitat: Sewage filter beds.

23. **Pseudomonas scissa** (Frankland and Frankland) Migula. (*Bacillus scissus* G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 298; Migula, System der Bakt., 1900, 927.)

Rods: 0.3 to 0.5 by 1.0 micron, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, greenish.

Gelatin stab: Thin, smooth, glistening surface growth, irregular, serrate margin. No liquefaction. The medium becomes light green in color.

Agar slant: Smooth, glistening, lobed. The medium assumes a greenish color.

Broth: Turbid, with whitish sediment.

Litmus milk: Not coagulated.
Potato: Glistening, reddish-brown growth.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Water.

24. **Pseudomonas denitrificans** Bergey et al. (*Bacillus denitrificans fluorescens* Christensen, Cent. f. Bakt., II Abt., *11*, 1903, 191; Bergey et al., Manual, 1st ed., 1923, 131.)

Rods: 0.5 to 0.7 by 0.5 to 1.25 microns, occurring singly and in pairs in large, slimy mass. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, circular, contoured, raised, moist, pearly-gray, glistening.

Gelatin stab: Whitish, lobed surface growth. Yellowish-green growth in stab. No liquefaction.

Agar colonies: Pearly white, circular, entire.
Agar slant: Broad, whitish, contoured, moist, entire.
Broth: Turbid, with thick, wrinkled pellicle.
Litmus milk: Not coagulated.
Potato: Reddish-gray layer.
Indol not formed.
Nitrates reduced to nitrogen.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Soil.

25. **Pseudomonas gelatica** (Gran) Bergey et al. (*Bacillus gelaticus* Gran, Bergens Museums Aarbog., 1902, 14; *Bacterium gelaticum* Lundstad, Cent. f. Bakt., II Abt., *75*, 1928, 328; Bergey et al., Manual, 3rd ed., 1930, 175.)

Rods with rounded ends, 0.6 to 1.2 by 1.2 to 2.6 microns, occurring singly, in pairs, and sometimes in short chains. Motile. Gram-negative.

Fish-gelatin colonies: Circular, transparent, glistening, becoming brownish in color.

Fish-gelatin stab: Liquefaction infundibuliform, with greenish color.

Sea-weed agar colonies: Circular, flat, entire, glistening, reddish-brown center with grayish-white periphery. Liquefied.

Fish-agar slant: Flat, transparent streak, with undulate margin, reddish-brown.

Broth: Turbid with flocculent pellicle, and greenish yellow sediment.
Litmus milk.
Potato.
Indol not formed.
Nitrates are reduced.

Starch hydrolyzed.
No action on sugars.
Aerobic, facultative.
Optimum temperature 20 to 25°C.
Habitat: Sea water of Norwegian coast.

26. **Pseudomonas pavonacea** Levine and Soppeland. (Bul. No. 77, Iowa State Agricultural College, 1926, 41.)

Rods: 0.5 by 4.5 microns, with truncate ends, occurring singly and in chains. Motile. Gram-negative.
Gelatin stab: Crateriform liquefaction. Medium becoming brown.
Agar colonies: Circular, raised, becoming green, amorphous, entire.
Agar slant: Greenish, smooth, glistening, viscid, medium becoming slightly brown.
Broth: Turbid, with viscid sediment. Medium turned dark brown.
Litmus milk: Alkaline. Litmus reduced.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Blood serum liquefied in 5 days.
No acid or gas in carbohydrate media.
Aerobic, facultative.
Optimum temperature 22°C.
Habitat: Isolated from activated sludge.

27. **Pseudomonas pierantonii** (Zirpolo) Bergey et al. (*Micrococcus pierantonii* Zirpolo, Boll. del. Societa dei Natural. in Napoli. *31*, 1918, 75; *Cocco-bacillus pierantonii* Meissner, Cent. f. Bakt., II Abt., *67*, 1926, 204; Bergey et al., Manual, 3rd ed., 1930, 176.)

Oval rods: 0.8 by 1.0 to 2.0 microns. Polymorphic rods, sometimes vacculated. Motile. Gram-negative.
Gelatin colonies: Circular, luminous.
Gelatin stab: Not liquefied.
Sepia agar colonies: Circular, white, convex, smooth, serrate edge. Intense greenish luminescens.
Egg-glycerin agar slant: Yellowish-green, luminous streak.
Broth: Turbid.
Litmus milk.
Potato.
Indol not formed.
Nitrates.
Acid in dextrose and maltose, some strains also produce acid in lactose and sucrose.
Best growth in alkaline media.
Aerobic.
Optimum temperature 33°C.

Habitat: Isolated from the photogenic organ of the cephalopod ***Rondeletia minor.***

28. **Pseudomonas smaragdina** Migula. (*Bacillus smaragdinus foetidus* Reiman, Inaug. dissertation, Würzburg, 1887; Migula, System der Bakterien, 1900, 890.)

Small rods, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, convex, irregular, whitish with greenish shimmer.

Gelatin stab: Slight surface growth. Infundibuliform liquefaction. The liquefied medium becomes light green in color.

Agar colonies: Small, brownish-yellow, convex.

Agar slant: Abundant growth with greenish fluorescence.

Broth: Turbid.

Litmus milk: Not coagulated.

Potato: Dark brown, becoming chocolate brown.

Indol not formed.

Nitrates not reduced

The cultures give off an odor resembling jasmine.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Isolated from nasal secretion in ozena.

29. **Pseudomonas chlorina** (Frankland and Frankland) Levine and Soppeland. (*Bacillus chlorinus*, G. and P. Frankland, Philos. Trans. Roy. Soc. London, *178*, 1887, 274; *Bacterium chlorinum* Le Blaye and Guggenheim, Manual pratique de diagnostique bacteriologique, Paris, 1914; Levine and Soppeland, Bul. No. 77, Iowa State Agricultural College, 1926.)

Rods: 0.5 by 1.0 micron, occurring singly. Non-motile. Gram-negative.

Gelatin stab: Crateriform liquefaction with green fluorescence.

Agar colonies: Circular, raised, smooth, amorphous, entire, becoming green.

Agar slant: Slightly raised, glistening, the medium becoming light green.

Broth: Moderate turbidity.

Litmus milk: Peptonized. Litmus reduced.

Potato: Scant, olive green growth.

Indol formed.

Nitrates reduced to nitrites.

Starch hydrolyzed.

Blood serum liquefied in 5 days.

Acid in glucose.

Aerobic, facultative.

Optimum temperature 22°C.

Habitat: Water.

30. **Pseudomonas non-liquefaciens** Bergey et al. (*Bacillus fluorescens non-liquefaciens* Eisenberg, Bakt. Diagnostik, III, 1891, 145; Bergey et al., Manual, 1st ed., 1923, 132.)

Short, slender rods, with rounded ends, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Fern-like surface colonies. Medium around colonies has a pearly luster.

Gelatin stab: Surface growth has fluorescent shimmer. No liquefaction.

Agar slant: Greenish layer.

Broth: Turbid, fluorescent.

Litmus milk: Unchanged.

Potato: Diffuse, brownish layer. Medium acquires a grayish-blue color.

Indol is not formed.

Nitrates not reduced.

Acid in dextrose.

Blood serum liquefied.

Aerobic, facultative.

Optimum temperature 25°C.

Not pathogenic.

Habitat: Water.

31. **Pseudomonas phosphorescens** (Fischer) Bergey et al. (*Bacillus phosphorescens* Fischer, Zeitschr. f. Hyg., *2*, 1887, 58; *Photobacterium phosphorescens* Beijerinck, Cent. f. Bakt., *8*, 1890, 617; Bergey et al., Manual, 3rd ed., 1930, 177.)

Short, thick rods with rounded ends, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Circular, grayish-white, sea-green, later becoming dirty brown in color, showing concentric rings.

Gelatin stab: No liquefaction.

Agar slant: Grayish-white layer.

Broth: Slight turbidity with thin pellicle.

Litmus milk: No growth.

Potato: Thin, whitish streak.

Growth on boiled fish: Abundant.

Luminescence: Deep, emerald-green.

Aerobic, facultative.

Optimum temperature 10 to 20°C.

Habitat: Isolated from luminous sea fish.

TRIBE II. PROTAMINOBACTERIEAE BERGEY ET AL., 1929.

Water and soil bacteria, non-pigment forming or producing red or yellow pigment, growing moderately or poorly on ordinary culture media. Capable of attacking the lower alkylamines. A single genus is recognized.

Genus Protominobacter den Dooren de Jong.

Genus V. **Protaminobacter** *Nijgh and Van Ditmore, 1926.*

Non-motile, gram-negative rods, capable of attacking one or more of the lower alkylamines, growing moderately or poorly on ordinary peptone agar. These bacteria are especially endowed to attack substances containing the group $\mathrm{HN}{<}^{\mathrm{C}}_{\mathrm{C}}$.

The type species is *Protaminobacter alboflavum a* den Dooren de Jong.

Key to species of genus **Protaminobacter.**

1. Agar colonies show pigment.
   a. Red pigment formed.
      b. Gelatin colonies yellow.
         1. *Protaminobacter alboflavum a.*
      bb. Gelatin colonies red.
         2. *Protaminobacter rubrum.*
   aa. Yellow pigment formed.
      b. Gelatin colonies yellow.
         3. *Protaminobacter alboflavum b.*
   aaa. Gray pigment formed.
      b. Gelatin colonies yellow.
         4. *Protaminobacter alboflavum c.*
2. Agar colonies show no pigment.
   a. Gelatin colonies colorless.
      5. *Protaminobacter alboflavum d.*

1. **Protaminobacter alboflavum a** den Dooren de Jong. Cent. f. Bakt., II, *71*, 1927, 218.)

Rods: Non-motile. Gram-negative.

Gelatin colonies: Circular, light yellow, dry.

Gelatin stab: No liquefaction.

Agar colonies: Circular, opaque, bright red.

Amin agar colonies: Circular, yellow.

The following organic acids are attacked: Acetic, valerianic, *a*-crotonic, lactic, *b*-oxybutyric, succinic, formic, fumaric, malic, citric, *b*-phenylpropionic and quinic.

The following amino compounds are attacked: *a*-aminocapronic acid, leucin, propionamid, capronamid, uric acid and hippuric acid.

The following amins are attacked: Ethyl, diethyl, propyl, dipropyl, tripropyl, butyl, isobutyl, diisobutyl, amyl, ethanol, glucosamin, benzyl, ethyl uric, *as*-diethyl uric.

The following are attacked: Dextrose and ethyl alcohol.

Catalase formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil and water.

2. **Protaminobacter rubrum** den Dooren de Jong. (Cent. f. Bakt., II, Abt., *71*, 1927, 218.)

Rods: Non-motile. Gram-negative.

Gelatin colonies: Circular, red, dry.

Gelatin stab: No liquefaction.

Agar colonies: Circular, red, opaque.

Amin agar colonies: Circular, dark red.

The following organic acids are attacked: Acetic, lactic, *b*-oxybutyric, glycerinic, succinic, malonic, formic, methyl formic, glutaric, maleinic, fumaric, malic, tartaric, citric and quinic.

The following amino compounds are attacked: Sarcosin, betain, hippuric acid, asparagine, propionamid, capronamid, lactamid, succinamid, allantoin and uric acid.

The following carbohydrates are attacked: Dextrose.

Catalase formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil and water.

3. **Protaminobacter alboflavum b** den Dooren de Jong. (Cent. f. Bakt., II Abt., *71*, 1927, 218.)

Rods: Non-motile. Gram-negative.

Gelatin colonies: Circular, light yellow, dry.

Gelatin stab: No liquefaction.

Agar colonies: Circular, opaque, yellow.

Amin agar colonies: Circular, dark yellow.

The following organic acids are attacked: Acetic, valerianic, *a*-crotonic, *b*-oxybutyric, succinic, formic, glutaric, fumaric, malic, tartaric, citric and quinic.

The following amino compounds are attacked: Leucin.

The following amins are attacked: Ethyl, diethyl, propyl, dipropyl, ipropyl, isobutyl, diisobutyl, amyl, diamyl, ethanol and glucosamin.

The following are attacked: Dextrose and ethyl alcohol.

Catalase formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil and water.

4. **Protaminobacter alboflavum c** den Dooren de Jong. (Cent. f. Bakt., II Abt., *71*, 1927, 218.)

Rods: Non-motile. Gram-negative.

Gelatin colonies: Circular, light yellow, dry.

Gelatin stab: No liquefaction.

Agar colonies: Circular, light gray, opaque.

Amin agar colonies: Circular, yellow.

The following organic acids are attacked: Acetic, *a*-crotonic, *b*-oxybutyric, succinic, formic, fumaric, malic and citric.

The following amino compounds are attacked: *a*-alanin, *a*-aminocapronic acid, propionamid and capronamid.
The following amins are attacked: Ethyl, propyl, butyl, isobutyl, amyl, ethanol, glucosamin and benzyl.
The following are attacked: Dextrose and ethyl alcohol.
Catalase formed.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil and water.

5. **Protaminobacter alboflavum** den Dooren de Jong. (Cent. f. Bakt., II Abt., *71*, 1927, 218.)
Rods: Non-motile. Gram-negative.
Gelatin colonies: Circular, colorless, dry.
Gelatin stab: No liquefaction.
Agar colonies: Circular, colorless, opaque.
Amin agar colonies: Circular, white.
The following organic acids are attacked: Acetic, valerianic, *a*-crotonic, undecylic, lactic, *b*-oxybutyric, succinic, formic, glutaric, adipic, fumaric, malic and citric.
The following amino compounds are attacked: *a*-alanin.
The following amins are attacked: Ethyl, propyl, isobutyl, amyl, ethanol and ethyl uric.
The following are attacked: Ethyl alcohol.
Catalase formed.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil and water.

TRIBE III. CELLULOMONADEAE BERGEY ET AL., 1923.

Short rods, occurring in soil, having the property of digesting cellulose. Motile, or non-motile. Chromogenic or non-chromogenic. Growth on ordinary culture media often not vigorous. Gram-negative.
There is a single genus *Cellulomonas*.

Genus VI. Cellulomonas *Bergey et al., 1923.*

Small rods, with rounded ends, non-spore-forming, motile or non-motile, occurring in soil and having the property of digesting cellulose.
The type species is *Cellulomonas biazotea* (Kellerman) Bergey et al.

Key to the species of genus Cellulomonas.

I. Motile with peritrichous flagella.
   1. Gelatin liquefied. Chromogenic.
      a. Milk acid.
      b. Ammonia not produced; indol not formed.
         1. *Cellulomonas biazotea.*

aa. Milk acid; digested.
b. Ammonia produced; indol not formed.
2. *Cellulomonas aurogenes.*
bb. Ammonia produced; indol formed.
3. *Cellulomonas galba.*
aaa. Milk alkaline.
b. Ammonia produced; indol not formed.
4. *Cellulomonas rossica.*
bb. Ammonia produced.
5. *Cellulomonas folia.*
aaaa. Litmus milk unchanged.
6. *Cellulomonas flava.*
2. Gelatin liquefied. Non-chromogenic.
a. Milk acid.
b. Ammonia not produced; indol not formed.
7. *Cellulomonas cellasea.*
bb. Ammonia produced; indol formed.
8. *Cellulomonas bibula.*
bbb. Ammonia produced; indol not formed.
9. *Cellulomonas iugis.*
bbbb. Ammonia not produced; indol formed.
10. *Cellulomonas concitata.*
aa. Milk acid; digested.
b. Ammonia produced; indol not formed.
11. *Cellulomonas casei.*
3. Gelatin not liquefied. Chromogenic.
a. Milk acid.
b. Ammonia produced; indol formed.
12. *Cellulomonas gilva.*
aa. Milk alkaline.
b. Ammonia not produced; indol not formed.
13. *Cellulomonas ferruginea.*
4. Gelatin not liquefied. Non-chromogenic.
a. Milk acid; not digested.
b. Ammonia not produced; indol not formed.
14. *Cellulomonas albida.*
15. *Cellulomonas alma.*
16. *Cellulomonas deciduosa.*
aa. Milk acid; digested.
b. Ammonia produced; indol not formed.
17. *Cellulomonas pusila.*
18. *Cellulomonas gelida.*
II. Motile with polar flagella.
1. Gelatin liquefied. Chromogenic.
a. Milk alkaline.
b. Ammonia produced; indol not formed.
19. *Cellulomonas effusa.*

aa. Milk acid; digested.
b. Ammonia produced; indol not formed.
20. *Cellulomonas perlurida.*

2. Gelatin liquefied. Non-chromogenic.
a. Milk acid.
b. Ammonia produced; indol formed.
21. *Cellulomonas minuscula.*

3. Gelatin not liquefied. Non-chromogenic.
a. Milk unchanged.
b. Ammonia not produced; indol not formed.
22. *Cellulomonas subcreta.*

aa. Milk acid.
b. Ammonia not produced; indol not formed.
23. *Cellulomonas tralucida.*
24. *Cellulomonas arguata.*

aaa. Milk alkaline.
b. Ammonia produced; indol not formed.
25. *Cellulomonas mira.*

III. Non-motile.
1. Gelatin liquefied. Chromogenic.
a. Milk acid.
b. Ammonia not produced; indol not formed.
26. *Cellulomonas idonea.*
27. *Cellulomonas flavigena.*

bb. Ammonia produced; indol formed.
28. *Cellulomonas liquata.*

2. Gelatin liquefied. Non-chromogenic.
a. Milk acid.
b. Ammonia produced; indol formed.
29. *Cellulomonas fima.*

bb. Ammonia produced; indol not formed.
30. *Cellulomonas uda.*

3. Gelatin not liquefied. Non-chromogenic.
a. Milk unchanged.
b. Ammonia not produced; indol not formed.
31. *Cellulomonas lucrosa.*

aa. Milk acid.
a. Ammonia not produced; indol not formed.
32. *Cellulomonas acidula.*
33. *Cellulomonas costigata.*

1. **Cellulomonas biazotea** (Kellerman et al.) Bergey et al. (*Bacillus biazoteus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., ***39***, 1913, 506; Bergey et al., Manual, 1st ed., 1923, 158.)

Rods: 0.5 by 0.8 micron. Motile with one to three peritrichous flagella. Gram-negative.
Gelatin stab: Liquefaction.
Agar slant: Luxuriant, yellow growth.
Broth: Turbid.
Litmus milk: Acid.
Potato: Grows well.
Indol not formed.
Nitrates reduced to nitrites.
Ammonia not produced.
Acid in dextrose, levulose, arabinose, xylose, maltose, lactose, sucrose, dextrin, starch, salicin, raffinose and glycerol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

2. **Cellulomonas aurogenes** (Kellerman et al.) Bergey et al. (*Bacillus aurogenes* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 505; Bergey et al., Manual, 1st ed., 1923, 157.)
Rods: 0.4 by 1.4 microns. Motile with one to three peritrichous flagella Gram-negative.
Gelatin stab. Liquefaction.
Agar colonies.
Agar slant: Luxuriant, yellow growth
Broth: Turbid.
Litmus milk: Acid; digested.
Potato: Luxuriant growth.
Indol not formed.
Nitrates reduced to nitrites.
Ammonia produced
Acid in dextrose, maltose, lactose, sucrose, starch and glycerol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

3. **Cellulomonas galba** (Kellerman et al.) Bergey et al. (*Bacillus galbus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 509; Bergey et al., Manual, 1st ed., 1923, 157.)
Rods: 0.4 by 1.0 micron. Motile with one to three peritrichous flagella. Gram-negative.
Gelatin stab: Liquefaction.
Agar slant: Luxuriant, yellow growth.
Broth: Turbid.
Litmus milk: Acid; digested.
Potato: No growth.
Indol is formed.
Nitrates not reduced.

Ammonia produced.
Acid in dextrose, maltose, lactose, sucrose, starch and glycerol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

4. **Cellulomonas rossica** (Kellerman and McBeth) Bergey et al. (*Bacillus rossicus* Kellerman and McBeth, Cent. f. Bakt., II Abt., *34*, 1912, 492; Bergey et al., Manual, 1st ed., 1923, 157.)

Rods: 0.3 by 1.2 microns. Motile with one to five peritrichous flagella. Gram-negative.
Gelatin stab: Liquefaction.
Agar slant: Luxuriant, yellow growth.
Broth: Turbid.
Litmus milk: Alkaline.
Potato: Grows well.
Indol not formed.
Nitrates reduced to nitrites.
Ammonia produced.
No acid formed in carbohydrate media
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

5. **Cellulomonas folia** Sanborn. (Jour. of Bact., *12*, 1926, 1 and 343.)

Rods: 0.8 to 1.0 by 1.0 to 1.5 microns, occurring singly and in short chains. Motile with four to six peritrichous flagella. Gram-negative.
Gelatin stab: Slow crateriform liquefaction, becoming stratiform.
Agar colonies.
Agar slant: Moderate, dirty-white, echinulate, raised, glistening, opaque, butyrous.
Broth: Turbid with yellowish sediment.
Litmus milk: Alkaline.
Potato: Thick, moist, yellowish-brown.
Indol not formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose, sucrose, glycerol and mannitol.
Starch hydrolyzed.
Ammonia formed.
H_2S not formed.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Isolated from decomposing leaves.

6. **Cellulomonas flava** Sack. (Cent. f. Bakt., II Abt., *62*, 1924, 79.)

Rods: 0.2 by 1.5 microns. Motile. Gram-negative.
Gelatin colonies: Circular, citron yellow.

Gelatin stab: Very slow liquefaction.
Agar colonies: Large, circular, citron yellow.
Agar slant: Abundant, citron yellow streak.
Broth: Turbid with pellicle and sediment.
Litmus milk: Unchanged.
Potato: Light brown streak.
Indol not formed.
Nitrates reduced to nitrites and ammonia.
H_2S formed.
Cellulose hydrolyzed.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

7. **Cellulomonas cellasea** (Kellerman et al.) Bergey et al. (*Bacillus cellaseus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., 39, 1913, 508; Bergey et al., Manual, 1st ed., 1923, 158.)

Rods: 0.5 by 1.2 microns. Motile with one to three peritrichous flagella. Gram-negative.
Gelatin stab: Liquefaction.
Agar slant: Limited grayish growth.
Broth: Clear.
Litmus milk: Acid.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Ammonia not produced.
Acid in dextrose, maltose, lactose, sucrose, starch, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

8. **Cellulomonas bibula** (McBeth and Scales) Bergey et al. (*Bacillus bibulus* McBeth and Scales, Bur. of Plant Industry, U. S. Dept. of Agr., Bul. No. 266, 1913, 35; Bergey et al., Manual, 1st ed., 1923, 158.)

Rods: 0.4 by 1.3 microns. Motile with one to four peritrichous flagella. Gram-negative.
Gelatin stab: Crateriform liquefaction.
Cellulose agar colonies: Circular, convex, smooth, soft, grayish to faintly yellowish-white, finely granular.
Agar slant: Luxuriant, glistening, smooth, moist, raised.
Broth: Slightly turbid.
Litmus milk: Faintly acid.
Potato: Smooth, glistening, canary yellow growth.
Indol is formed.
Nitrates not reduced.
Ammonia is produced.

Acid in dextrose, levulose, arabinose, xylose, maltose, lactose, sucrose, dextrin, starch, salicin, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

9. **Cellulomonas iugis** (McBeth) Bergey et al. (*Bacillus iugis* McBeth, Soil Science, 1, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 158.)

Rods: 0.4 by 1.4 microns. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Napiform liquefaction.

Agar colonies: Circular, convex, soft, grayish-white, granular, entire.

Agar slant: Scant, grayish-white, filiform growth.

Broth: Turbid.

Litmus milk: Acid; not digested.

Potato: Abundant, glistening, grayish-white.

Indol not formed.

Nitrates reduced to nitrites.

Ammonia produced.

Acid in dextrose, maltose, lactose, sucrose, starch, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

10. **Cellulomonas concitata** (McBeth) Bergey et al. (*Bacillus concitatus* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 159.)

Rods: 0.5 by 1.2 microns. Motile with one to four peritrichous flagella. Gram-negative.

Gelatin stab: Napiform liquefaction.

Agar colonies: Irregularly circular, decidedly convex, soft, becoming viscid, grayish-white, sometimes slightly fluorescent, granular, entire.

Agar slant: Abundant, flat, moist, faint yellowish-white.

Broth: Turbid.

Litmus milk: Acid, not digested.

Potato: No growth.

Indol is formed.

Nitrates not reduced.

Ammonia not produced.

Acid in dextrose, maltose, lactose, sucrose, starch and glycerol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

11. **Cellulomonas casei** (Kellerman et al.) Bergey et al. (*Bacillus caseius* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 507; Bergey et al., Manual, 1st ed., 1923, 159.)

Rods: 0.4 by 1.5 microns. Motile with one or two peritrichous flagella. Gram-negative.

Gelatin stab: Liquefaction.

Broth: Turbid.

Litmus milk: Acid; digested.

Potato: No growth.

Indol not formed.

Nitrates reduced to nitrites.

Ammonia produced.

Acid in dextrose, maltose, lactose, sucrose, starch, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

12. **Cellulomonas gilva** (McBeth) Bergey et al. (*Bacillus gilvus* McBeth. Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 160.)

Rods: 0.5 by 1.5 microns. Motile with one to five peritrichous flagella. Gram-negative.

Gelatin stab: Moderate, yellowish-white surface growth. No liquefaction.

Agar colonies: Circular, convex, butyrous canary-yellow, sometimes with brownish rings, granular, entire.

Agar slant: Filiform, yellowish-white.

Broth: Slightly turbid.

Litmus milk: Acid; not digested.

Potato: Abundant, canary-yellow growth.

Indol is formed.

Nitrates reduced to nitrites.

Ammonia is produced.

Acid in dextrose, maltose, lactose, sucrose, starch and glycerol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

13. **Cellulomonas ferruginea** (Rullmann) Bergey et al. (*Bacillus ferrugineus* Rullmann, Cent. f. Bakt., I Abt., Orig., *24*, 1898, 465; van Iterson, Cent. f. Bakt., II Abt., *11*, 1904, 689; Bergey et al., Manual, 1st ed., 1923, 160.)

Rods: 0.5 to 0.8 by 1.5 to 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Brown, the pigment diffusing into the medium.

Gelatin stab: No liquefaction.

Agar slant: Rusty-brown streak.

Broth: Turbid.

Litmus milk: Dark-yellow ring; alkaline.

Potato: Rusty-brown streak.

Indol not formed.
Nitrates not reduced.
Ammonia not produced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Water.

14. **Cellulomonas albida** (McBeth) Bergey et al. (*Bacillus albidus* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 160.)

Rods: 0.4 by 1.0 microns. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Scant growth. No liquefaction.
Agar colonies: Circular, convex, soft, grayish-white, granular, entire.
Agar slant: Scant, white streak.
Broth: Clear.
Litmus milk: Slightly acid, not digested.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Ammonia not produced.
Acid in dextrose, maltose, lactose, sucrose, starch, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

15. **Cellulomonas alma** (McBeth) Bergey et al. (*Bacillus almus* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 161.)

Rods: 0.5 by 1.2 microns. Motile with one to five peritrichous flagella. Gram-negative.

Gelatin stab: Scant growth. No liquefaction.

Agar colonies: Circular, convex, soft, becoming brittle, grayish-white, granular, entire.

Agar slant: Scant, grayish-white, becoming yellowish-white.
Broth: Slightly turbid.
Litmus milk: Slightly acid; not digested.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Ammonia not produced.
Acid in dextrose, maltose, lactose, sucrose, starch, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

16. **Cellulomonas deciduosa** (McBeth) Bergey et al. (*Bacillus deciduosus* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 162.)

Rods: 0.4 by 1.0 micron. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: Moderate growth. No liquefaction.

Agar colonies: Circular, slightly convex, soft, becoming somewhat viscid, grayish-white, granular, entire.

Agar slant: Scant, flat, grayish-white.

Broth: Slightly turbid.

Litmus milk: Acid; not digested.

Potato: No growth.

Indol is formed.

Nitrates reduced to nitrites.

Ammonia not produced.

Acid in dextrose, lactose, maltose and starch.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

17. **Cellulomonas pusilla** (Kellerman et al.) Bergey et al. (*Bacillus pusillus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 513; Bergey et al., Manual, 1st ed., 1923, 161.)

Rods: 0.6 by 1.1 microns. Motile with one to three peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar slant: Scant growth, grayish-white.

Broth: Turbid.

Litmus milk: Acid.

Potato: No growth.

Indol not formed.

Nitrates reduced to nitrites.

Ammonia is produced.

Acid in dextrose, maltose, lactose, sucrose, starch and glycerol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

18. **Cellulomonas gelida** (Kellerman et al.) Bergey et al. (*Bacillus gelidus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 510; Bergey et al., Manual, 1st ed., 1923, 162.)

Rods: 0.4 by 1.2 microns. Motile with one to three peritrichous flagella Gram-negative.

Gelatin stab: No liquefaction.

Agar slant: Luxuriant, grayish-white growth.

Broth: Turbid.

Litmus milk: Acid; peptonized.

Potato: Grows well.

Indol not formed.

Nitrates not reduced.

Ammonia is produced.

Acid in dextrose, levulose, arabinose, xylose, maltose, lactose, sucrose, dextrin, starch, salicin and glycerol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

19. **Cellulomonas effusa** (Kellerman et al.) Bergey et al. (*Bacillus effusus* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 515; Bergey et al., Manual, 1st ed., 1923, 162.)

Rods: 0.4 by 1.7 microns. Motile with one to six polar flagella. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Luxuriant, yellow growth.

Broth: Turbid.

Litmus milk: Alkaline. Peptonization.

Potato: Good growth.

Indol not formed.

Nitrates reduced to nitrites.

Ammonia is produced.

Acid in dextrose, maltose, starch, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

20. **Cellulomonas perlurida** (Kellerman et al.) Bergey et al. (*Pseudomonas perlurida* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 516; Bergey et al., Manual, 1st ed., 1923, 163.)

Rods: 0.4 by 1.0 micron. Motile with one to three polar flagella. Gram-negative.

Gelatin stab: Liquefaction.

Agar slant: Luxuriant, yellow growth.

Broth: Turbid.

Litmus milk: Acid. Peptonization.

Potato: Good growth.

Indol not formed.

Nitrates not reduced.

Ammonia is produced.

Acid in dextrose, levulose, arabinose, xylose, maltose, lactose, sucrose, dextrin, starch, salicin, glycerol and mannitol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

21. **Cellulomonas minuscula** (McBeth) Bergey et al. (*Pseudomonas minuscula* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 162.)

Rods: 0.5 by 0.9 micron. Motile with one to two polar flagella. Gram-negative.

Gelatin stab: Moderate growth. Slight napiform liquefaction.

Agar colonies: Small, circular, slightly convex, butyrous becoming brittle, grayish-white, finely granular, entire.

Agar slant: Moderate, flat, grayish-white.

Broth: Turbid.

Litmus milk: Acid; not digested.

Potato: No apparent growth.

Indol is formed.

Nitrates reduced to nitrites.

Ammonia is produced.

Acid in dextrose, lactose, maltose, sucrose and starch.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

22. **Cellulomonas subcreta** (McBeth and Scales) Bergey et al. (*Pseudomonas subcreta* McBeth and Scales, Bur. Plant Industry, U. S. Dept. of Agr., Bul. No. 266, 1913, 37; Bergey et al., Manual, 1st ed., 1923, 164.)

Rods: 0.4 by 1.4 microns. Motile with one to five polar flagella. Gram-negative.

Gelatin stab: No liquefaction.

Cellulose agar colonies: Circular, concave, yellowish-gray, granular, entire.

Agar slant: Glistening, smooth, moist, vitreous to faint yellow.

Broth: Clear.

Litmus milk: Unchanged.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Ammonia not produced

Acid in dextrose, lactose, maltose, sucrose and starch.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

23. **Cellulomonas tralucida** (Kellerman et al.) Bergey et al. (*Pseudomonas tralucida* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 517; Bergey et al. Manual, 1st ed., 1923, 163.)

Rods: 0.6 by 1.2 microns. Motile with one or two polar flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar slant: Scant, grayish growth.

Broth: Turbid.

Litmus milk: Acid.

Potato: No growth.

Indol not formed.
Nitrates reduced to nitrites.
Ammonia not produced.
Acid in dextrose, maltose, lactose, sucrose, starch, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

24. **Cellulomonas arguata** (McBeth) Bergey et al. (*Pseudomonas arguata* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 164.)

Rods: 0.3 by 0.8 micron. Motile with one or two polar flagella. Gram-negative.
Gelatin stab: Moderate, faintly yellowish growth. No liquefaction.
Agar colonies: Circular, slightly convex, soft, grayish-white, granular, entire.
Agar slant: Scant, grayish-white growth.
Broth: Turbid.
Litmus milk: Acid, not digested.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Ammonia not produced.
Acid in dextrose, maltose, lactose, starch and glycerol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

25. **Cellulomonas mira** (McBeth) Bergey et al. (*Pseudomonas mira* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 165.

Rods: 0.4 by 1.6 microns. Motile with a single polar flagellum. Gram-negative.
Gelatin stab: Good growth. No liquefaction
Agar colonies: Circular, convex, grayish-white, granular, lacerate.
Agar slant: Moderate, flat, grayish-white, somewhat iridescent
Broth: Turbid.
Litmus milk: Alkaline.
Potato: Moderate, grayish-white.
Indol not formed.
Nitrates reduced to nitrites.
Ammonia is produced.
Acid in dextrose, maltose, lactose, sucrose, starch, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

26. **Cellulomonas idonea** (McBeth) Bergey et al. (*Bacterium idoneum* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 165.)

Rods: 0.5 by 1.5 microns. Non-motile. Gram-negative.
Gelatin stab: Moderate, yellowish. Slight napiform liquefaction.
Agar colonies: Circular, convex, soft, becoming brittle, grayish, granular, entire.
Agar slant: Scant, yellowish-white, becoming distinctly yellow.
Broth: Turbid.
Litmus milk: Acid; not digested.
Potato: Abundant, moist, glistening, grayish-white, becoming distinctly yellow.
Indol not formed.
Nitrates reduced to nitrites.
Ammonia not produced.
Acid in dextrose, maltose, lactose, starch and glycerol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

27. **Cellulomonas flavigena** (Kellerman and McBeth) Bergey et al. (*Bacterium flavigenum* Kellerman and McBeth, Cent. f. Bakt., II Abt., *34*, 1912, 488; Bergey et al., Manual, 1st ed., 1923, 165.)
Rods: 0.4 by 1.0 micron. Non-motile. Gram-negative.
Gelatin stab: Liquefaction.
Agar slant: Luxuriant, yellow growth.
Broth: Turbid.
Litmus milk: Acid.
Potato: Grows well.
Indol not formed.
Nitrates reduced to nitrites.
Ammonia not produced.
Acid in dextrose, levulose, arabinose, xylose, maltose, lactose, sucrose, dextrin, starch, inulin, salicin, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

28. **Cellulomonas liquata** (McBeth and Scales) Bergey et al. (*Bacterium liquatum* McBeth and Scales, Bur. of Plant Industry, U. S. Dept of Agr., Bul. No. 266, 1913, 32; Bergey et al., Manual, 1st ed., 1923, 166.)
Rods: 0.4 by 1.7 microns. Non-motile. Gram-negative.
Gelatin stab: Liquefaction napiform, becoming stratiform.
Cellulose agar colonies: Circular, raised or umbonate, smooth, yellowish-gray finely granular, entire.
Agar slant: Luxuriant, yellow growth.
Broth: Turbid, with slight sediment.
Litmus milk: Faintly acid.
Potato: Abundant, raised, glistening, smooth, canary-yellow.

Indol is formed.
Nitrates reduced to nitrites.
Ammonia is produced.
Acid in dextrose, levulose, arabinose, xylose, maltose, lactose, sucrose, raffinose, melezitose, dextrin, starch, salicin and glycerol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

29. **Cellulomonas fima** (McBeth and Scales) Bergey et al. (*Bacterium fimum* McBeth and Scales, Bur. of Plant Industry, U. S. Dept.of Agr., Bul. No. 266, 1913, 30; Bergey et al., Manual, 1st ed., 1923, 166.)
Rods: 0.4 by 0.9 micron. Non-motile. Gram-negative.
Gelatin stab: Infundibuliform liquefaction.
Cellulose agar colonies: Circular, raised, smooth, shiny, slightly gray, granular, entire.
Agar slant: Smooth, glistening moist, white to vitreous.
Broth: Slightly turbid.
Litmus milk: Faintly acid.
Potato: Moderate, smooth, glistening, cream colored growth.
Indol formed.
Nitrates reduced to nitrites.
Ammonia is produced.
Acid in dextrose, levulose, arabinose, xylose, maltose, lactose, sucrose, raffinose, melezitose, dextrin, starch, salicin and glycerol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

30. **Cellulomonas uda** (Kellerman et al.) Bergey et al. (*Bacterium udum* Kellerman, McBeth, Scales and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 514; Bergey et al., Manual, 1st ed., 1923, 166.)
Rods: 0.5 by 1.5 microns. Non-motile. Gram-negative.
Gelatin stab: Liquefaction.
Agar slant: Luxuriant, faintly yellowish growth.
Broth: Turbid.
Litmus milk: Acid.
Potato: Good growth.
Indol not formed.
Nitrates reduced to nitrites
Ammonia is produced.
Acid in dextrose, levulose, arabinose, xylose, maltose, lactose, sucrose, dextrin and starch.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

31. **Cellulomonas lucrosa** (McBeth) Bergey et al. (*Bacterium lucrosum* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 167.)

Rods: 0.4 by 1.3 microns. Non-motile. Gram-negative.
Gelatin stab: No growth.
Agar colonies: Circular, convex, semi-transparent, granular, entire.
Agar slant: Moderate, flat, grayish-white, becoming somewhat iridescent.
Broth: Turbid.
Litmus milk: No change.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Ammonia not produced.
Acid in dextrose, maltose, lactose, sucrose, starch and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

32. **Cellulomonas acidula** (Kellerman et al.) Bergey et al. (*Bacterium acidulum* Kellerman, McBeth, Scales, and Smith, Cent. f. Bakt., II Abt., *39*, 1913, 513; Bergey et al., Manual, 1st ed., 1923, 167.)

Rods: 0.3 by 1.0 micron. Non-motile. Gram-negative.
Gelatin stab: No liquefaction
Agar slant: Slight, grayish growth.
Broth: Clear
Litmus milk: Acid
Potato: No growth
Indol not formed.
Nitrates not reduced.
Ammonia not produced.
Acid in dextrose, maltose, lactose and sucrose.
Aerobic.
Optimum temperature 20°C.
Habitat: Soil.

33. **Cellulomonas costigata** (McBeth) Bergey et al. (*Bacterium costigatum* McBeth, Soil Science, *1*, 1916, 437; Bergey et al., Manual, 1st ed., 1923, 168.)

Rods: 0.4 by 1.2 microns. Non-motile. Gram-negative.
Gelatin stab: Moderate surface growth. No liquefaction.
Agar colonies: Circular, slightly convex, brittle, grayish-white, granular, entire.
Agar slant: Abundant, glistening, grayish-white.
Broth: Slightly turbid.
Litmus milk: Acid, not digested.
Indol not formed.
Nitrates not reduced.

Ammonia not produced.
Acid in dextrose, maltose, lactose, sucrose, starch and glycerol.
Aerobic.
Optimum temperature 20°C.
Habitat: Soil.

TRIBE IV. ACHROMOBACTERIEAE BERGEY ET AL., 1923.

Rods, small to medium in size, occurring principally in water and soil. Form no pigment on agar or gelatin but may produce a brownish growth on potato. Cultural characters variable. Some species form acid in simple sugars, others are without action on carbohydrates. Motile or non-motile. Gram-negative.

There is a single genus *Achromobacter*.

Genus VII. Achromobacter *Bergey et al., 1923.*

Non-pigment forming (at most no pigment formed on agar or gelatin) rods, occurring in water and soil. Motile or non-motile. Gram-negative

The type species is *Achromobacter liquefaciens* (Eisenberg) Bergey et al.

Key to the species of genus Achromobacter.

A. Motile rods. Flagella peritrichous.
 1. Gelatin liquefied.
  a. Growth on potato.
  b. Milk unchanged.
  c. Nitrates not reduced.
  d. Indol not formed.
   1. *Achromobacter liquefaciens.*
   2. *Achromobacter stoloniferum.*
   3. *Achromobacter formosum.*
   4. *Achromobacter nitrificans.*
   5. *Achromobacter gasoformans.*
  cc. Nitrates reduced.
  d. Indol not formed
   6. *Achromobacter dendriticum.*
  bb. Milk acid.
  c. Nitrates reduced.
  d. Indol not formed.
   7. *Achromobacter delicatulum.*
   8. *Achromobacter hyalinum.*
   9. *Achromobacter iophagum.*
  cc. Nitrates not reduced.
  d. Indol not formed.
   10. *Achromobacter healii.*

bbb. Milk coagulated, peptonized, becoming alkaline.

11. *Achromobacter lipolyticum.*

bbbb. Milk acid, coagulated, gas.

12. *Achromobacter aceris.*

aa. Do not grow on potato.

b. Milk unchanged.

c. Nitrates not reduced.

d. Indol not formed.

13. *Achromobacter litorale.*

2. Gelatin not liquefied.

a. Growth on potato.

b. Milk unchanged.

c. Nitrates reduced.

d. Indol not formed.

14. *Achromobacter agile.*
15. *Achromobacter hartlebii.*
16. *Achromobacter centropunctatum.*
17. *Achromobacter pestifer.*
18. *Achromobacter stutzeri.*

cc. Nitrates not reduced.

d. Indol not formed.

19. *Achromobacter guttatum.*
20. *Achromobacter inunctum.*
21. *Achromobacter venosum.*
22. *Achromobacter album.*
23. *Achromobacter visco-symbioticum.*

bb. Milk alkaline.

c. Nitrates reduced.

d. Indol is formed.

24. *Achromobacter geminum.*
25. *Achromobacter pinnatum.*

cc. Nitrates not reduced.

d. Indol not formed.

26. *Achromobacter solitarium.*
27. *Achromobacter rugosum.*
28. *Achromobacter ravenelii.*

bbb. Milk slightly acid.

c. Nitrates not reduced.

d. Indol not formed.

29. *Achromobacter superficiale.*

cc. Action on nitrates not reported.

30. *Achromobacter butyri.*

bbbb. Milk acid; coagulated.

c. Nitrates reduced.

d. Indol not formed.

31. *Achromobacter reticularum.*

cc. Nitrates not reduced.
d. Indol not formed.
32. *Achromobacter stearophilum.*
aa. Growth on potato not reported.
b. Nitrates reduced.
33. *Achromobacter cycloclastes.*
bb. Nitrates not reduced.
34. *Achromobacter alcaliaromaticum.*
B. Motile rods. Flagella polar.
1. Gelatin liquefied.
a. Growth on potato.
b. Milk unchanged.
c. Nitrates reduced.
d. Indol not formed.
35. *Achromobacter liquidum.*
bb. Milk alkaline; litmus reduced.
c. Nitrates not reduced.
d. Indol not formed.
36. *Achromobacter nebulosum.*
37. *Achromobacter geniculatum.*
dd. Indol is formed.
38. *Achromobacter fairmountense.*
bbb. Litmus milk alkaline; peptonized.
c. Nitrates not reduced.
d. Indol not formed.
39. *Achromobacter pellucidum.*
cc. Nitrates reduced.
40. *Achromobacter putrifaciens.*
bbbb. Milk slightly acid; coagulated
c. Nitrates not reduced.
d. Indol not formed.
41. *Achromobacter multistriatum.*
42. *Achromobacter radiobacter.*
dd. Indol is formed.
43. *Achromobacter punctatum.*
44. *Achromobacter coadunatum.*
2. Gelatin not liquefied.
a. Growth on potato.
b. Milk unchanged.
c. Nitrates not reduced.
d. Indol is formed.
45. *Achromobacter sinosum.*
aa. Growth on potato not reported.
b. Action on milk not reported.
c. Nitrates reduced.
46. *Achromobacter rathonis.*
47. *Achromobacter pictorum.*

48. *Achromobacter desmolyticum.*
49. *Achromobacter dacunhae.*

cc. Nitrates not reduced.

50. *Achromobacter arvillum.*
51. *Achromobacter cruciviae.*
52. *Achromobacter salopium.*

bb. Milk acid; coagulated.
c. Nitrates not reduced.
d. Indol is formed.

53. *Achromobacter ambiguum.*

C. Motile. Flagellation undetermined.
1. Gelatin liquefied.
a. Growth on potato.
b. Milk peptonized.
c. H_2S is formed.

54. *Achromobacter sulfureum.*

bb. Milk unchanged.
c. H_2S is formed.

55. *Achromobacter halophilum.*

aa. No growth on potato.
b. Phosphorescent.

56. *Achromobacter fischeri.*
57. *Achromobacter argentophosphorescens.*
58. *Achromobacter cyaneophosphorescens.*
59. *Achromobacter phosphoreum.*

bb. Not phosphorescent.

60. *Achromobacter granii.*

2. Gelatin not liquefied.
a. Growth on potato.
b. Milk unchanged.

61. *Archromobacter pikowskyi.*

aa No growth on potato.
b. Phosphorescent.

62. *Achromobacter phosphoricum.*

bb. Not phosphorescent.
c. H_2S is formed.

63. *Achromobacter galophilum.*

cc. H_2S not formed.
d. Nitrates reduced.

64. *Archromobacter citrophilum.*
65. *Archromobacter aerophilum.*

dd. Nitrates not reduced.

66. *Achromobacter amylovorum.*

D. Non-motile rods.
  1. Gelatin liquefied.
    a. Growth on potato.
    b. Milk unchanged.
    c. Nitrates not reduced.
    d. Indol not formed.
    e. Phosphorescent.
      67. *Achromobacter smaragdinophosphorescens.*
    ee. Not phosphorescent.
    c. Nitrates reduced.
      68. *Achromobacter globiforme.*
  2. Gelatin not liquefied.
    a. Growth on potato.
    b. Milk slimy, not coagulated.
    c. Nitrates not reduced.
    d. Indol formed.
    e. Phosphorescent.
      69. *Achromobacter luminosum.*
    ee. Not phosphorescent.
      70. *Achromobacter nenckii.*
      71. *Achromobacter larvae.*
    bb. Milk slimy; becoming alkaline.
    c. Nitrates not reduced.
    d. Indol not formed.
      72. *Achromobacter eurydice.*
    bbb. Milk alkaline.
    c. Nitrates not reduced.
    d. Indol not formed.
      73. *Achromobacter candicans.*
      74. *Achromobacter connii.*
      75. *Achromobacter refractum.*
      76. *Achromobacter tiogense.*
      77. *Achromobacter rodonatum.*
    bbbb. Milk acid.
    c. Nitrates not reduced.
    d. Indol not formed.
      78. *Achromobacter aromafaciens.*
      79. *Achromobacter middletownii.*
      80. *Achromobacter acidum.*
      81. *Achromobacter lacticum.*
    bbbbb. Milk acid; coagulated.
    c. Nitrates not reduced.
    d. Indol not formed.
      82. *Achromobacter coccoideum.*

cc. Nitrates reduced to nitrites.

d. Indol not formed.

83. *Achromobacter fermentationis.*

84. *Achromobacter ubiquitum.*

ccc. Nitrates reduced to nitrogen.

d. Indol not formed.

85. *Achromobacter filifaciens.*

86. *Achromobacter nitrovorum.*

1. **Achromobacter liquefaciens** (Eisenberg) Bergey et al. (*Bacillus liquefaciens* Eisenberg, Bakt. Diagnostik, 1891, 112; Frankland and Frankland, Microorganisms in Water, 1894, 461; Bergey et al., Manual, 1st ed., 1923, 135.)

Short, rather thick rods, with rounded ends, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, gray, entire.

Gelatin stab: Napiform liquefaction.

Agar slant: Dirty-white, spreading.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Light yellow streak.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Water.

2. **Achromobacter stoloniferum** (Pohl) Bergey et al. (*Bacillus stoloniferus* Pohl, Cent. f. Bakt., *11*, 1892, 142; Bergey et al., Manual, 1st ed., 1923, 136.)

Rods: 0.8 by 1.2 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, white, entire.

Gelatin stab: Infundibuliform liquefaction.

Agar slant: Thick, white, fimbriate.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: White, spreading.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Water.

3. **Achromobacter formosum** (Ravenel) Bergey et al. (*Bacillus formosus* Ravenel, Memoirs, Nat. Acad. Sci., *8*, 1896, 12; Bergey et al., Manual, 1st. ed., 1923, 136.)

Slender rods, seven to ten times as long as wide, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, grayish, granular, becoming concentrically ringed.

Gelatin stab: Crateriform to stratiform liquefaction.

Agar slant: White, moist, glistening, limited, undulate.

Broth: Turbid, with gray sediment.

Litmus milk: Litmus reduced.

Potato: White, moist, spreading.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

4. **Achromobacter nitrificans** (Chester) Bergey et al. (Nitratbildner aus Northeim, Burri and Stutzer, Cent. f. Bakt., II Abt., *1*, 1895, 735; *Bacillus nitrificans* Chester, Manual of Determinative Bacteriology, 1901, 239; Bergey et al., Manual, 1st ed., 1923, 137.)

Rods: 0.5 by 0.7 to 1.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, colorless, slimy.

Gelatin stab: Crateriform to napiform liquefaction.

Agar slant: Gray, slimy, plumose.

Broth: Slightly turbid with whitish sediment.

Litmus milk: Unchanged.

Potato: Gray, slimy streak.

Indol not formed.

Oxidizes nitrites to nitrates.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Soil.

5. **Achromobacter gasoformans** (Eisenberg) Bergey et al. (Gasbildner Bacillus, Tils, Zeitschr. f. Hyg., *9*, 1890, 315; *Bacillus gasoformans* Eisenberg, Bakt. Diagnostik, 1891, 107; Bergey et al., Manual, 1st ed., 1923, 137.)

Small rods, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, gray.

Gelatin stab: Saccate to infundibuliform liquefaction with much gas formation.

Agar colonies: Circular, white, marmorated.

Agar slant: Dirty-white, smooth, glistening.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Slimy, yellowish, becoming brownish.

Indol not formed.

Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25° to 30°C.
Habitat: Water.

6. **Achromobacter dendriticum** (Lustig) Bergey et al. (*Bacillus dendriticus* Lustig, Diagnostik der Bakterien des wassers, 1893, 99; Bergey et al., Manual, 2nd ed., 1925, 156.).

Rods: 0.5 to 0.8 by 0.8 to 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Large, white, raised, moist, glistening, amoeboid.
Gelatin stab: Slow, crateriform liquefaction.
Agar slant: Thin, iridescent layer.
Broth: Turbid, with tough, adherent pellicle.
Litmus milk: Unchanged.
Potato: White, moist, glistening, rough.
Indol not formed.
Nitrates are reduced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Water.

7. **Achromobacter delicatulum** (Jordan) Bergey et al. (*Bacillus delicatulus* Jordan, Report Mass. State Bd. of Health, 1890, 837; Bergey et al., Manual, 1st ed., 1923, 137.)

Rods: 0.1 by 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Whitish, homogeneous, with radiate margin.
Gelatin stab: Infundibuliform liquefaction.
Agar slant: Whitish, glistening.
Broth: Turbid, with gray pellicle and sediment.
Litmus milk: Acid.
Potato: Thin, gray streak.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Water.

8. **Achromobacter hyalinum** (Jordan) Bergey et al. (*Bacillus hyalinus* Jordan, Report Mass. State Bd. of Health, 1890, 835; Bergey et al., Manual, 1st ed., 1923, 138.)

Rods: 1.0 by 5.0 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Gray, villous.
Gelatin stab: Saccate to infundibuliform liquefaction.
Agar slant: Dull, gray, dry, tough.

Broth: Turbid, with pellicle.
Litmus milk: Acid, coagulated.
Potato: Dull, gray, dry, tough.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 25° to 30°C.
Habitat: Water.

9. **Achromobacter iophagum** (Gray and Thornton) Bergey et al. (*Bacterium iophagum* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 89; Bergey et al., Manual, 3rd ed., 1930, 204.)

Rods: 0.8 to 1.0 by 1.0 to 5 0 microns. Motile by means of peritrichous flagella. Gram-negative.
Gelatin colonies: Quickly liquefied.
Gelatin stab: Liquefied.
Agar colonies: Circular or amoeboid, whitish, flat, raised, smooth, translucent, entire.
Agar slant: Filiform, white to buff, flat, undulate.
Broth: Turbid.
Litmus milk: Unchanged.
Potato.
Indol.
Nitrates reduced to nitrites.
Starch hydrolyzed.
Acid formed in dextrose and sucrose
Attack phenol and naphthalene.
Aerobic, facultative.
Optimum temperature 30 to 35°C.
Habitat: Soil.

10. **Achromobacter healii** (Buchanan and Hammer) Bergey et al. (*Bacterium healii* Buchanan and Hammer, Iowa Agr. Exp. Sta., Research Bull. 22, 1915; *Escherichia healii* Bergey et al., Manual, 1st ed., 1923, p. 200; Bergey et al., Manual, 2nd ed., 1925, 157.)

Rods: 0.5 to 0.7 by 2.2 to 12.9 microns, occurring singly and in short chains. Non-motile. Gram-negative.
Gelatin stab: Stratiform liquefaction. Villous growth in stab.
Agar colonies: Large, white, rhizoid.
Agar slant: White, hard with no tendency to stringiness.
Broth: Gray pellicle and sediment.
Litmus milk: Slightly acid, becoming slimy, coagulated, peptonized.
Potato: Heavy, white glistening.
Indol not formed.
Nitrates not reduced.
No gas in carbohydrate media.
Aerobic, facultative.

Optimum temperature 22°C.
Habitat: Slimy milk.

11. **Achromobacter lipolyticum** (Huss) Bergey et al. (*Bactridium lipolyticum* Huss, Cent. f. Bakt., II Abt., *20*, 1908, 474; Bergey et al., Manual, 2nd ed., 1925, 158.)

Small, oval rods, 0.3 to 0.5 by 0.7 to 1.4 microns. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, grayish to transparent with irregular margin.
Gelatin stab: Infundibuliform liquefaction.
Agar colonies: Circular, gray, smooth, glistening, with entire margin
Broth: Turbid, with granular sediment.
Litmus milk: Coagulated, peptonized, becoming alkaline.
Potato: Moist, glistening, grayish growth.
Indol is formed.
Nitrates.
Acid is formed in dextrose, sucrose, raffinose, xylose, mannitol and glycerol.
Fats are split in milk, giving rise to rancid odor and bitter taste.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Milk.

12. **Achromobacter aceris** (Edson and Carpenter) *comb. nov.* (*Bacillus aceris* Edson and Carpenter, Vermont Agr. Exp. Sta. Bull. No. 167, 1912, 475.)

Rods, 0.9 to 1.0 by 1.5 to 3.0 microns, with rounded ends, occurring singly and in chains. Motile with peritrichous flagella. Encapsulated. Gram-negative.

Gelatin colonies: Circular, gray, lobed, convex, with dark alveolar center.
Gelatin stab: Villous growth in stab. Slow napiform liquefaction in 20 days.
Agar colonies. Circular, gray, contoured with concentric rings. Lobate margin.
Agar slant; Echrinulate, gray, raised center, contoured.
Broth: Turbid with membranous pellicle and viscid sediment.
Litmus milk: Acid, gas, coagulation with extrusion of whey.
Potato: Gray, slimy streak. Gas and alcohol formed.
Indol is formed.
Nitrates.
Acid and gas in dextrose, maltose, lactose, sucrose, mannitol and maple syrup.
Ammonia is formed.
H_2S is not formed.
Starch is not hydrolyzed.
Optimum temperature 25°C.

Aerobic, facultative.
Habitat: Isolated from maple syrup.

13. **Achromobacter litorale** (Russell) Bergey et al. (*Bacillus litoralis* Russell, Zeitschr. f. Hyg., *11*, 1891; Bergey et al., Manual, 1st ed., 1923, 138.)

Rods: 0.5 to 0.6 by 2.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: White, opalescent, entire.
Gelatin stab: Slow, crateriform liquefaction.
Agar slant: White, slimy.
Broth: Turbid, with gray pellicle and sediment.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25° to 30°C.
Habitat: Isolated from mud bottom of Gulf of Naples.

14. **Achromobacter agile** (H. Jensen) Bergey et al. (*Bacillus denitrificans agilis* Ampola and Garino, Cent. f. Bakt., II Abt., *2*, 1896, 673; *Bacterium agile* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 408; *Bacillus denitrificans* Migula, System der Bakterien, 1900, 796; Not *Bacillus denitrificans* Chester, Determinative Bacteriology, 1901, 274; Bergey et al., Manual, 1st ed., 1923, 138.)

Rods: 0.3 to 0.5 by 1.0 to 2.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Small, white, homogeneous, entire.
Gelatin stab: Grayish-white surface growth. No liquefaction.
Agar colonies: Small, white, slimy.
Agar slant: Limited, grayish-white, slimy.
Broth: Turbid, with pellicle.
Litmus milk: Unchanged.
Potato: Limited, grayish-white.
Indol not formed.
Nitrates reduced to nitrogen.
Aerobic, facultative.
Optimum temperature 25° to 30°C.
Habitat: Isolated from cow manure.

15. **Achromobacter hartlebii** (H. Jensen) Bergey et al. (*Bacillus hartlebii* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 449; Bergey et al., Manual, 1st ed., 1923, 139.)

Rods: 0.7 by 2.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Small, white, translucent, entire, to erose margin.

Gelatin stab: White, slimy growth on surface. No liquefaction.
Agar colonies: Small, white, translucent, slimy, entire.
Agar slant: Thick, grayish-white, moist, glistening, watery.
Broth: Turbid, with pellicle.
Litmus milk: Unchanged.
Potato: Grayish-white, moist.
Indol not formed.
Nitrates reduced to nitrogen.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil.

16. **Achromobacter centropunctatum** (H. Jensen) Bergey et al. (*Bacillus centropunctatus* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 410; Bergey et al., Manual, 1st ed., 1923, 139.)

Rods: 0.3 by 0.5 micron, occurring singly. Encapsulated. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Thin, grayish, moist, soft, flat, glistening.

Gelatin stab: White, fimbriate, spreading surface growth. No liquefaction.

Agar colonies: Gray, moist, glistening, slimy.
Agar slant: Thin, grayish, moist, center raised, becoming thick.
Broth: Turbid, with pellicle.
Litmus milk: Unchanged.
Potato: Grayish, slimy.
Indol not formed.
Nitrates reduced to nitrogen.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Isolated from cow manure.

17. **Achromobacter pestifer** (Frankland and Frankland) Bergey et al. (*Bacillus pestifer* G. and P. Frankland, Philosoph. Trans. Royal Soc., London, B, *178*, 1888, 277; Bergey et al., Manual, 1st ed., 1923, 140.)

Rods: 0.1 by 2.3 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Gray, smooth, with wavy bundles of chains along border.

Gelatin stab: Gray surface growth. Villous growth in stab. No liquefaction.

Agar slant: Translucent, smooth, glistening.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Gray, filiform growth.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.

Optimum temperature 25°C.
Habitat: Isolated from air.

18. **Achromobacter stutzeri** (Lehmann and Neumann) Bergey et al. (*Bacillus denitrificans II*, Burri and Stutzer, Cent. f. Bakt., II Abt., *1*, 1895, 392; *Bacterium stutzeri* Lehmann and Neumann, Bakt. Diagnostik, *2*, 1896, 237; Bergey et al., Manual, 3rd ed., 1930, 207.)

The relationship of *Achromobacter stutzeri* to the following organisms is not clear. Kultur No. 3, Sewerin, Cent. f. Bakt., II. Abt., *1*, 1895, 162; *Vibrio denitrificans* Sewerin, Cent. f. Bakt., II Abt., *3*, 1897, 517; *Achromobacter sewerinii* Bergey et al., Manual, 1st ed., 1923, 140.

Rods: 0.5 by 2.0 to 4.0 microns, occurring singly and in short chains. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Small, white, entire.
Gelatin stab: No liquefaction.
Agar colonies: Small, bluish-white, homogeneous, entire.
Agar slant: Grayish-white, slimy, undulate.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: White, slimy.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 25°C
Habitat: Horse manure.

19. **Achromobacter guttatum** (Zimmermann) Bergey et al. (*Bacillus guttatus* Zimmermann, Bakt. unserer Trink- u. Nutzwässer, Chemnitz, 1890, 56; Bergey et al., Manual, 1st ed., 1923, 140.)

Rods: 0.9 by 1.0 micron, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Small, circular, gray, entire.
Gelatin stab: No liquefaction.
Agar colonies: Small, gray, homogeneous, entire.
Agar slant: Gray, limited.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Yellowish-gray, slimy.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25° to 30°C.
Habitat: Water.

20. **Achromobacter inunctum** (Pohl) Bergey et al. (*Bacillus inunctus* Pohl, Cent. f. Bakt., *11*, 1892, 143; Bergey et al., Manual, 1st ed., 1923, 141.)

Rods: 0.8 to 0.9 by 3.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, gray, circular, entire. Arborescent growth in stab. No liquefaction.
Agar slant: White, smooth, glistening.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: White slimy.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25° to 30°C.
Habitat: Water.

21. Achromobacter venosum (Vaughan) Bergey et al. (*Bacillus venosus* Vaughan, American Jour. Med. Sci., 1892, 107; Bergey et al., Manual, 1st ed., 1923, 141.)
Rods: 0.5 to 0.6 by 1.0 to 2.0 microns, with rounded ends, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: White, convex, smooth, glistening, entire.
Gelatin stab: White surface growth. No liquefaction.
Agar colonies: Small, white, entire.
Agar alant: Thin, white, homogeneous, entire.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Moist, glistening, light brown.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Water.

22. Achromobacter album (Copeland) Bergey et al. (*Bacillus albus* Copeland, Report of Filtration Commission, Pittsburgh, 1899, 348; Bergey et al., Manual, 1st ed., 1923, 141.)
Rods: 0.5 by 1.0 to 1.5 microns, with rounded ends. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Small, white to pearly gray, raised, glistening.
Gelatin stab: Thin, white, surface growth. No liquefaction.
Agar colonies: Circular, wnite, homogeneous, entire.
Agar slant: Luxuriant, white, wax-like.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Dirty-white, luxuriant.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Water.

23. **Achromobacter visco-symbioticum** (Buchanan and Hammer) Bergey et al. (*Bacillus visco-symbioticum* Buchanan and Hammer, Research Bull. 22, Iowa Agr. Exp. Sta., 1915, 261; *Escherichia symbiotica* Bergey et al., Manual, 1st ed., 1923, 202; Bergey et al., Manual, 3rd ed., 1930, 209.)

Rods: 0.4 to 0.5 by 0.7 to 2.7 microns, occurring singly. Motile. Gram-negative.

Gelatin stab: Heavy, white surface growth. No liquefaction.

Agar colonies: Large, white, raised, undulate.

Agar slant: Heavy, white spreading.

Broth: Turbid, with gray sediment.

Litmus milk: Unchanged.

Potato: Luxuriant, dirty white, spreading.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Ropy milk.

24. **Achromobacter geminum** Bergey et al. (*Bacillus geminus minor* Ravenel, Memoirs, Nat. Acad. Sci., *8*, 1896, 28; Bergey et al., Manual, 1st ed., 1923, 142.)

Very short rods, two to four times as long as wide, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: White, granular, raised, convex, entire.

Gelatin stab: Raised surface growth. No liquefaction.

Agar slant: Thin, whitish, smooth, glistening, spreading.

Broth: Turbid, with thin pellicle.

Litmus milk: Alkaline.

Potato: Dirty-white, moist, glistening, spreading.

Indol formed.

Nitrates reduced to nitrites.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Soil.

25. **Achromobacter pinnatum** (Ravenel) Bergey et al. (*Bacillus pinnatus* Ravenel, Memoirs, Nat. Acad. Sci., *8*, 1896, 32; Bergey et al., Manual, 1st ed., 1923, 142.)

Slender rods, three to five times as long as wide, occurring singly and in pairs. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, white, with yellowish-brown center, granular.

Gelatin stab: White, umbilicate. No liquefaction.

Agar slant: Thin, moist, glistening, watery.

Broth: Turbid, with flaky pellicle and sediment.

Litmus milk: Alkaline.

Potato: Dirty-brown, thin, moist, glistening.

Indol is formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Soil.

26. **Achromobacter solitarium** (Ravenel) Bergey et al. (*Bacillus solitarius* Ravenel, Memoirs, Nat. Acad. Sci. *8*, 1896, 29; Bergey et al., Manual, 1st ed., 1923, 143.)

Slender rods, three to seven times as long as wide, with rounded ends, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Circular, grayish, floccose to filamentous.
Gelatin stab: Raised, umbilicate, gray. No liquefaction.
Agar colonies: Circular, gray, filamentous.
Agar slant: White, moist, glistening, spreading.
Broth: Turbid.
Litmus milk: Alkaline.
Potato: Thin, whitish, becoming thick, dull gray.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Soil.

27. **Achromobacter rugosum** (Chester) Bergey et al. (Bacillus No. 27, Conn, Storrs' Agr. Exp. Sta., 1893, 54; *Bacillus rugosus* Chester, Determinative Bacteriology, 1901, 220; Not *Bacillus rugosus* Wright, Memoirs, Nat. Acad. Sci., *7*, 1895, 438; Bergey et al., Manual, 1st ed., 1923, 143.)

Rods: 0.8 by 1.2 to 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Gray, raised, translucent, spreading, wrinkled margin
Gelatin stab: Thin, transparent surface growth. No liquefaction.
Agar slant: White, raised, spreading.
Broth: Turbid, with gray pellicle and sediment.
Litmus milk: Alkaline; peptonized.
Potato: Thick, yellowish, spreading.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative
Optimum temperature 30° to 35°C.
Habitat: Milk.

28. **Achromobacter ravenelii** (Chester) Bergey et al. (*Bacillus geminus major* Ravenel, Memoirs, Nat. Acad. Sci., *8*, 1896, 27; *Bacillus raveneli* Chester, Determinative Bacteriology, 1901, 217; Bergey et al., Manual, 1st ed., 1923, 143.)

Thick rods, of variable length, occurring singly and in short chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Leaf-like, gray, granular, undulate.

Gelatin stab: Gray surface growth, arborescent in stab. No liquefaction.

Agar slant: Gray, translucent, spreading.

Broth: Turbid.

Litmus milk: Slightly alkaline.

Potato: Yellow, moist, glistening, becoming chocolate-brown.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

29. **Achromobacter superficiale** (Jordan) Bergey et al. (*Bacillus superficialis* Jordan, Report Mass. State Bd. of Health, 1890, 833; Bergey et al., Manual, 1st ed., 1923, 144.)

Rods: 1.0 by 2.2 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, circular, gray, translucent.

Gelatin stab: Scanty surface growth. No liquefaction.

Agar slant: Limited, gray, filiform.

Broth: Slightly turbid.

Litmus milk: Slightly acid.

Potato: Limited, dirty-white streak.

Indol not formed.

Nitrates not reduced

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Sewage.

30. **Achromobacter butyri** Bergey et al. (*Micrococcus butyri-aromafaciens* Keith, The Technology Quarterly, *10*, 1897, 247; *Bacillus butyri aromaticus* Grimm, Cent. f. Bakt., II Abt., *8*, 1902, 589; Bergey et al., Manual, 1st ed., 1923, 148.)

Rods: 0.5 to 1.0 micron, nearly spherical, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: White, circular, smooth, glistening.

Gelatin stab: White surface growth, liquefaction.

Agar slant: Abundant, white, glistening.

Broth: Turbid, with gray ring and sediment.

Litmus milk: Unchanged.

Potato: Slow and limited, grayish growth.

Indol not formed.

Nitrates not reduced.

Pleasant odor in milk culture.

Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Milk.

31. **Achromobacter reticularum** (Jordan) Bergey et al. (*Bacillus reticularis* Jordan, Report Mass. State Bd. of Health, 1890, 834; Bergey et al., Manual, 1st ed., 1923, 144.)

Rods: 1.0 by 5.0 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Gray, irregular.
Gelatin stab: Irregular, gray growth on surface. Arborescent growth in stab. No liquefaction.
Agar slant: Gray, dry, dull, spreading.
Broth: Turbid, with ropy sediment.
Litmus milk: Acid; coagulated.
Potato: White, dull, dry, spreading.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Water.

32. **Achromobacter stearophilum** (Weinzirl) Bergey et al. (*Bacillus stearophilus* Weinzirl, Jour. of Med. Research, *39*, 1919, 404; Bergey et al., Manual, 1st. ed., 1923, 145.)

Rods: 0.8 by 5.0 microns, occurring singly. Motile. Gram-positive.
Gelatin colonies: Scanty development.
Pumpkin gelatin stab: Filiform growth in stab. No liquefaction.
Pumpkin agar colonies: Small, smooth, convex, gray, entire.
Pumpkin juice: Slightly turbid.
Pumpkin milk: Acid; coagulated.
Potato: Slight, smooth, gray, glistening, filiform.
Indol not formed.
Nitrates not reduced.
No acid formed in carbohydrate media.
Starch from pumpkin hydrolyzed.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Canned pumpkin.

33. **Achromobacter cycloclastes** (Gray and Thornton) Bergey et al. (*Bacterium cycloclastes* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 89; Bergey et al., Manual, 3rd ed., 1930, 212.)

Rods: 1.0 to 1.5 by 1.5 to 3.0 microns. Motile with peritrichous flagella. Gram-negative.
Gelatin colonies: Circular, white, raised, smooth, glistening, entire.
Gelatin stab: No liquefaction.

Agar colonies: Circular to amoeboid, white, flat to convex, smooth, glistening, translucent with opaque center, entire.
Agar slant: Filiform, pale buff, raised, smooth, glistening, undulate.
Broth: Turbid.
Litmus milk.
Potato.
Indol.
Nitrates reduced to nitrites.
Starch not hydrolyzed.
No acid in carbohydrate media.
Attack phenol and naphthalene.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Soil.

34. **Achromobacter alcaliaromaticum** (Berlin) Bergey et al. (*Bacterium alcaliaromaticum* Berlin, Rev. de Microbiol. et Epidemiol., *6*, 1927; Bergey et al., Manual, 3rd ed., 1930, 212.)
At 18 to 20°C. on agar or gelatin, rods 0.2 to 0.4 micron in thickness by 0.5 to 0.8 micron in length.
At 37°C.: Motile, with peritrichic flagella. Gram-negative.
Gelatin colonies: Small, with raised center, whitish.
Gelatin stab: No liquefaction.
Agar colonies: Small, circular, with entire margin, whitish, opaque, center raised.
Broth: Turbid, alkaline.
Milk: Alkaline.
Potato.
Indol not formed.
Nitrates not reduced.
H_2S not produced.
Carbohydrates not attacked.
Aerobic, facultative.
Optimum temperature 77°C.
Habitat: Intestinal tract.

35. **Achromobacter liquidum** (Frankland and Frankland) Bergey et al. (*Bacillus liquidus* G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 382; Bergey et al., Manual, 1st ed., 1923, 145.)
Rods: 0.6 by 1.2 to 5.0 microns, occurring singly. Motile, possessing polar flagella. Gram-negative.
Gelatin colonies: Circular, white, with granular margin.
Gelatin stab: Saccate to infundibuliform liquefaction.
Agar slant: Gray, translucent, smooth, glistening.
Broth: Turbid, with gray pellicle and sediment.
Litmus milk: Unchanged.
Potato: Thick, flesh-colored, rough, moist.

Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Water.

36. **Achromobacter nebulosum** (Wright) Bergey et al. (*Bacillus nebulosus* Wright, Memoirs Nat. Acad. Sci., 7, 1894, 465; Bergey et al., Manual, 1st ed., 1923, 145; not *Bacillus nebulosus* Goresline, Jour. Bact., *27*, 1934, 52.)

Medium-sized rods, occurring singly. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Thin, circular, gray, translucent, hazy, with white center.

Gelatin stab: Crateriform liquefaction.
Agar slant: Thin, transparent streak.
Broth: Turbid, with gray sediment.
Litmus milk: Alkaline; reduction of litmus.
Potato: Scanty growth.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Water.

37. **Achromobacter geniculatum** (Wright) Bergey et al. (*Bacillus geniculatus*, Memoirs Nat. Acad. Sci., 7, 1894, 459; Bergey et al., Manual, 1st ed., 1923, 146.)

Medium-sized rods, occurring singly, in pairs and chains. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, whitish, translucent.
Gelatin stab: Infundibuliform liquefaction.

Agar slant: Grayish, glistening, translucent, limited, becoming brownish-gray.

Broth: Turbid, with slight gray pellicle and sediment.
Litmus milk: Alkaline; reduction of litmus; slight coagulation.
Potato: Thin, brownish, moist, glistening, viscid.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 20° to 25°C.
Habitat: Water.

38. **Achromobacter fairmountense** (Wright) Bergey et al. (*Bacillus fairmountensis*, Memoirs Nat. Acad. Sci., 7, 1894, 458; Bergey et al., 1st. ed., 1923, 146.)

Medium-sized rods, occurring singly, in pairs and in chains. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, white, translucent.
Gelatin stab: Crateriform liquefaction.
Agar slant: Grayish-white, glistening.
Broth: Turbid.
Litmus milk: Alkaline, litmus reduced.
Potato: Raised, granular, spreading, viscid.
Indol is formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 20° to 25°C.
Habitat: Water.

39. **Achromobacter pellucidum** Harrison. (Canadian Jour. of Research, *1*, 1929, 236.)

Rods: 0.6 by 1.2 to 2.0 microns, occurring singly, in pairs and in short chains. Encapsulated. Motile with monotrichous flagella. Gram-negative.

Gelatin colonies: Circular, whitish, granular, entire.
Gelatin stab: Infundibuliform to saccate liquefaction.
Agar colonies: Circular, dirty white, pulvinate, shiny, granular, entire.
Agar slant: Slightly raised, moist, white, shiny streak.
Broth: Pellicle with shiny sediment.
Litmus milk: Alkaline. Peptonized.
Potato: Scant to no growth.
Indol not formed.
Nitrates not reduced.
Traces of ammonia formed.
No action on dextrose, lactose or sucrose.
Loeffler's blood serum liquefied.
Anaerobic, facultative.
Optimum temperature 20° to 25°C.
Habitat: Isolated from living halibut obtained at 30 to 50 fathoms Pacific Ocean.

40. **Achromobacter putrefaciens** Derby and Hammer. (Derby and Hammer, Research Bulletin, No. 145, Iowa Agr. Exp. Sta., 1931, 401.)

Rods: 0.5 to 1.0 by 1.1 to 4.0 microns, occurring singly and in pairs. Motile, with a single flagellum. Gram-negative.

Gelatin stab: Rapid, saccate to stratiform liquefaction, with reddish-brown sediment in the liquefied portion.

Agar colony: Circular, smooth, glistening, slightly raised somewhat transparent, with brownish tinge.

Agar slant: Echinulate, slightly reddish-brown, viscous.
Broth: Turbid, with thin, gray pellicle, and reddish-brown sediment.
Litmus milk: Rapid reduction and proteolysis with odor of putrefaction.
Potato: Echinulate, smooth, glistening, viscous, reddish-brown.
Indol is not produced.

Nitrates are reduced to nitrites.

Acid formed in maltose and sucrose. No action on dextrose, levulose, galactose, arabinose, lactose, raffinose, dextrin, inulin, salicin, amygdalin, glycerol.

Ammonia is formed.

Aerobic, facultative.

Optimum temperature 21°C.

Habitat: Isolated from tainted butter.

41. **Achromobacter multistriatum** (Wright) Bergey et al. (*Bacillus multistriatus*, Memoirs Nat. Acad. Sci., *7*, 1894, 462; Bergey et al., Manual, 1st ed., 1923, 147.)

Medium-sized rods, with rounded ends, occurring singly and in pairs. Motile, possessing polar flagella. Gram-negative.

Gelatin colonies: Circular, grayish-white, translucent.

Gelatin stab: Crateriform liquefaction.

Agar slant: Narrow, translucent, grayish streak.

Broth: Turbid.

Litmus milk: Slightly acid; coagulated.

Potato: Grayish to creamy, thick, glistening, viscid, spreading.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Water.

42. **Achromobacter radiobacter** (Beijerinck and van Delden) *comb. nov.* (*Bacillus radiobacter* Beijerinck and van Delden, Cent. f. Bakt., II Abt., *9*, 1902, 3; *Bacterium radiobacter* Löhnis, and Hansen, Jour. Agr. Res., *20*, 1921, 543.)

Small rods, average size 0.5 by 1.1 microns, occurring singly, in pairs and under certain conditions, in star shaped clusters. Motile with one or more polar flagella, also reported as having peritrichous flagella. Gram negative.

Nutrient gelatin stab; No liquefaction; surface growth grayish, flat, often turning brownish in 2–4 weeks.

Agar slant: Flat, whitish slimy layer.

Mannitol glycerophosphate agar streak plates: Abundant, raised, slimy, growth surrounded by a brown halo with an outer zone of white precipitate.

Broth: Turbid, delicate pellicle, sediment.

Litmus milk: Serum zone with pellicle in one week; without litmus, milk below serum zone usually turns a chocolate brown in 2 weeks.

Potato: raised slimy mass becoming brownish, potato browned.

Nitrates disappear (assimilated or reduced).

Starch not hydrolyzed.

Acid formed in dextrose, sucrose, maltose, fructose, galactose, xylose, mannose and arabinose; no acid in dextrin, inulin, salicin, aesculin, dulcitol, mannitol, erythritol, raffinose, melezitose, lactose and rhamnose in the

peptone mineral salt medium VII (without xylose) of Riker et al., Jour. Agr. Res., *41*, 1930, 524.

Aerobic, facultative.

Optimum temperature 28°C.

Differentiation: Distinguishable from certain strains of *Phytomonas tumefaciens* by inability to produce crown galls, agglutination and reaction to bacteriophage; from certain strains of *Rhizobium* by inability to produce nodules, agglutination and reaction to bacteriophage.

Habitat: Soil, around the roots of plants, especially legumes.

43. **Achromobacter punctatum** (Zimmermann) Bergey et al. (*Bacillus punctatus* Zimmermann, Bakt. unserer Trink- und Nutzwässer, Chemnitz, 1890, 38; Bergey et al., Manual, 1st ed., 1923.)

Rods: 0.5 by 0.8 micron, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Small, circular, gray, erose to filamentous.

Gelatin stab: Crateriform liquefaction.

Agar slant: Gray, smooth, filamentous.

Broth: Turbid.

Litmus milk: Acid; coagulated; peptonized.

Potato: Gray, spreading.

Indol is formed.

Nitrates not reduced.

H_2S is formed.

Gas in dextrose broth.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Water.

44. **Achromobacter coadunatum** (Wright) Bergey et al. (*Bacillus coadunatus* Wright, Memoirs Nat. Acad. Sci., *7*, 1894, 460; Bergey et al., Manual, 1st ed., 1923, 147.)

Medium-sized rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Circular, brownish, dense.

Gelatin stab: Crateriform to stratiform liquefaction.

Agar slant: Gray, translucent, spreading.

Broth: Turbid, with gray pellicle and sediment.

Litmus milk: Acid; coagulated.

Indol is formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Water.

45. **Achromobacter sinuosum** (Wright) Bergey et al. (*Bacillus sinuosus* Wright, Memoirs Nat. Acad. Sci., *7*, 1894, 440; Bergey et al., Manual, 1st ed., 1923, 148.)

Medium-sized rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing two to four polar flagella. Gram-negative.

Gelatin colonies: Thin, translucent, irregular, center brownish.

Gelatin stab: Grayish-white, glistening, translucent. No liquefaction.

Agar slant: Scanty, grayish growth.

Broth: Turbid, with gray sediment.

Litmus milk: Unchanged.

Potato: Grayish-white, moist, spreading.

Indol is formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30° to 35°C.

Habitat: Water.

46. **Achromobacter rathonis** (Gray and Thornton) Bergey et al. (*Pseudomonas rathonis* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 90; Bergey et al., Manual, 3rd ed., 1930, 216.)

Small rods: 0.5 to 1.0 by 1.0 to 3.0 microns, motile, with polar flagella. Gram-negative.

Gelatin colonies: Circular, white, raised, smooth, glistening, undulate.

Gelatin stab: No liquefaction.

Agar colonies: Circular, buff, flat, smooth, glistening, entire.

Agar slant: Filiform, pale buff, convex, smooth, glistening, undulate.

Broth: Turbid, with pellicle.

Nitrates reduced to nitrites.

Starch hydrolyzed.

Acid formed in dextrose and glycerol.

Attack phenol and cresol at times, also naphthalene.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Manure and soil.

47. **Achromobacter pictorum** (Gray and Thornton) Bergey et al. (*Pseudomonas pictorum* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 89; Bergey et al., Manual, 3rd ed., 1930, 217.)

Rods: 0.5 to 0.8 by 1.5 to 5.0 microns. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Circular, greenish-yellow, convex, smooth, glistening, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular, yellow, convex, smooth, glistening, entire.

Agar slant: Filiform, yellow, convex, smooth, glistening, entire.

Broth: Turbid.

Nitrates reduced to nitrites.

Starch not hydrolyzed.

Acid in dextrose and maltose.

Attack phenol.

Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Soil.

48. **Achromobacter desmolyticum** (Gray and Thornton) Bergey et al. (*Pseudomonas desmolyticum* Gray and Thornton, Cent. of Bakt., II Abt., *73*, 1928, 90; Bergey et al., Manual, 3rd ed., 1930, 217.)

Rods: 0.7 to 0.8 by 2.0 to 3.0 microns, occurring singly and in pairs. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Circular, gray to buff, raised or umbonate. Smooth, glistening, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular or amoeboid, whitish, flat or convex, smooth, translucent to opaque, entire.

Agar slant: Filiform, pale buff, raised, smooth, undulate.
Broth: Turbid.
Nitrates reduced to nitrites.
Starch not hydrolyzed.
Acid formed in dextrose.
Attack phenol and naphthalene.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Soil.

49. **Achromobacter dacunhae** (Gray and Thornton) Bergey et al. (*Pseudomonas dacunhae* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 90; Bergey et al., Manual, 3rd ed., 1930, 217.)

Rods: 0.5 to 0.8 by 1.5 to 3.0 microns. Motile with one to six polar flagella. Gram-negative.

Gelatin colonies: Circular, whitish, raised, smooth, glistening, undulate.
Gelatin stab: No liquefaction.

Agar colonies: Circular to amoeboid, white, flat, glistening, opaque, entire.

Agar slant: Filiform, pale buff, raised, smooth, glistening, undulate.
Broth: Turbid.
Nitrates reduced to nitrites.
Starch not hydrolyzed.
No acid in carbohydrate media.
Attack phenol.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Soil.

50. **Achromobacter arvillum** (Gray and Thornton) Bergey et al. (*Pseudomonas arvilla* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 91; Bergey et al., Manual, 3rd ed., 1930, 218.)

Rods: 0.5 to 0.7 by 2.0 to 3.0 microns. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Circular, whitish, convex, smooth, glistening, lobate.

Gelatin stab: No liquefaction.

Agar colonies: Circular or amoeboid, white to buff, flat to convex, smooth, glistening, opaque, entire.

Agar slant: Filiform, whitish, concave, smooth, ringed, entire.

Broth: Turbid.

Nitrates not reduced.

Starch not hydrolyzed.

Acid formed in dextrose.

Attack naphthalene.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Soil.

51. **Achromobacter cruciviae** (Gray and Thornton) Bergey et al. (*Pseudomonas cruciviae* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 91; Bergey et al., Manual, 3rd ed., 1930, 218.)

Rods: 1.0 by 1.0 to 3.0 microns, occurring singly and in pairs. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: Circular, white with buff center, convex, smooth, undulate.

Gelatin stab: No liquefaction.

Agar colonies: Circular or amoeboid, white to buff, flat to convex, smooth, entire.

Agar slant: Filiform, pale buff, raised, smooth, undulate.

Broth: Turbid.

Nitrates not reduced.

Starch not hydrolyzed.

No acid in carbohydrate media.

Attack phenol and *m*-cresol.

Aerobic, facultative.

Optimum temperature 30 to 35°C.

Habitat: Soil.

52. **Achromobacter salopium** (Gray and Thornton) Bergey et al. (*Pseudomonas salopium* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 91; Bergey et al., Manual, 3rd ed., 1930, 219.)

Rods: 0.7 to 1.0 by 1.0 to 3.0 microns, occurring singly and in pairs. Motile with one to six polar flagella. Gram-negative.

Gelatin colonies: Circular, grayish-buff, flat, rugose or ringed, translucent border.

Gelatin stab: no liquefaction.

Agar colonies: Circular or amoeboid, white to buff, flat to convex, smooth, glistening, translucent border, entire.

Agar slant: Filiform, whitish, raised, smooth, glistening, lobate.
Broth: Turbid with pellicle.
Nitrates not reduced.
Starch not hydrolyzed.
Acid formed in dextrose and sucrose.
Attack naphthalene.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Soil.

53. **Achromobacter ambiguum** (Wright) Bergey et al. (*Bacillus ambiguus* Wright, Memoirs Nat. Acad. Sci., *7*, 1894, 439; Bergey et al., Manual, 1st ed., 1923, 148.)

Small rods, with rounded ends, occurring singly, in pairs and in chains. Motile, possessing a polar flagellum. Gram-negative.

Gelatin colonies: Gray, translucent, slightly raised, irregular, radiate, with transparent margin.

Gelatin stab: No liquefaction.
Agar slant: Gray, limited, entire.
Broth: Turbid, with gray sediment.
Litmus milk: Acid; slowly coagulated.
Potato: Gray to creamy, viscid, spreading.
Indol is formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Water.

54. **Achromobacter sulfureum** Bergey et al. (Bakt. 4, Rubentschick, Cent. f. Bakt., II Abt., *72*, 1927, 123; Bergey et al., Manual, 3rd ed 1930, 220.)

Rods: 0.7 to 0.8 by 1.7 to 2.2 microns, occurring singly and in pairs. Motile. Gram-positive.

Gelatin stab: Saccate liquefaction.
Agar colonies: Circular, grayish-white, flat, homogeneous.
Agar slant: Filiform, grayish-white, smooth, homogeneous.
Broth: Turbid.
Litmus milk: Peptonized.
Potato: Yellowish-brown layer.
Indol not formed.
Nitrates reduced with gas formation.
H_2S formed.
Ammonia formed.
Urea is attacked.
Methylene blue reduced.
Aerobic, facultative.
Can grow at 0°C.

Optimum temperature 20°C.
Habitat: Sewage filter beds.

55. **Achromobacter halophilum** Bergey et al. (Culture No. 36, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 220.)

Rods: 1.0 by 2.5 microns, with granular cytoplasm. Motile. Gram-negative.
Gelatin stab: Surface growth rose-colored. No liquefaction.
Agar colonies: Small, circular, opalescent.
Agar slant: Thin, grayish, transparent layer.
Broth: Turbid with pellicle.
Litmus milk: Unchanged.
Potato: Yellowish-white layer.
Indol not formed.
Nitrates not reduced
Ammonia formed.
H_2S formed.
Growth occurs in media with 25 per cent NaCl.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Sea water.

56. **Achromobacter fischeri** (Beijerinck) Bergey et al. (Fischer, Einheimscher Leuchtbacillus, Cent. f. Bakt., *3*, 1888, 107; *Photobacterium fischeri* Beijerinck, Verslagen en Mededeelingen d. Kon. Akad. v. Wetenschappen, Afd. Naturkunde, *7*, 1890, 239; *Bacillus phosphorescens indigenus* Kruse, in Flügge Die Mikroorganismen, 1896, 331; *Bacillus fischeri* Migula, System der Bakterien, 1900, 866; Bergey et al., Manual, 3rd ed., 1930, 220.)

Rods: 0.4 to 0.7 by 1.3 to 2.1 microns, with slightly pointed ends, somewhat curved, occurring singly and in pairs. Motile. Gram-positive.
Gelatin colonies: Circular, entire.
Gelatin stab: Slight infundibuliform liquefaction.
Agar slant.
Broth: No growth.
Litmus milk: No growth.
Potato: No growth.
Luminescent.
Aerobic, facultative.
Optimum temperature 20° to 25°C.
Habitat: Isolated from sea water.

57. **Achromobacter argenteophosphorescens** Bergey et al. (*Bacillus argenteo-phosphorescens I*, Katz, Cent. f. Bakt., *9*, 1891, 157; Bergey et al., Manual, 3rd ed., 1930, 221.)

Slightly curved rods with somewhat pointed ends, 0.8 by 2.5 microns. Motile. Gram-positive.

Gelatin colonies: Circular, clear, flat, homogeneous, serrate margin.
Gelatin stab: Liquefied.
Agar slant: Grayish, moderate.
Broth: Turbid with pellicle and sediment.
Litmus milk.
Potato: No growth.
Growth on boiled fish: Abundant, light yellow, moist, glistening, becoming greenish.
Luminescence: Silver-white.
Aerobic, facultative.
Optimum temperature 15° to 20°C.
Habitat: Isolated from sea water in Elizabeth Bay, Sydney, Australia.

58. **Achromobacter cyaneophosphorescens** (Katz) Bergey et al. (*Bacillus cyaneo-phosphorescens* Katz, Cent. f. Bakt., *9*, 1891, 157, 199, 229, 258, 311, 343; Bergey et al., Manual, 3rd ed., 1930, 221.)

Rods with rounded ends, 1.0 by 2.5 microns, occurring singly and in pairs. Motile. Gram-positive.
Gelatin colonies: Circular, flat, yellowish-gray, homogeneous to finely granular.
Gelatin stab: Infundibuliform liquefaction.
Agar slant: Gray, viscid, later with formation of secondary colonies.
Broth: Turbid, with pellicle and sediment.
Litmus milk: No growth.
Potato: No growth.
Growth on boiled fish: Abundant, yellowish, moist, glistening, viscid.
Luminescence: Bluish-green.
Aerobic, facultative.
Optimum temperature 15° to 20°C.
Habitat: From sea water in Little Bay, South of Sydney, Australia.

59. **Achromobacter phosphoreum** (Migula) Bergey et al. (*Bacillus argenteo-phosphorescens liquefaciens* Katz, Cent. f. Bakt., *9*, 1891, 157; *Bacillus phosphoreus* Migula, System der Bakterien, 1900, 867; Bergey et al., Manual, 3rd ed., 1930, 222.)

Straight or slightly curved rods, 0.6 to 0.7 by 2.0 microns, occurring in chains. Motile. Gram-negative.
Gelatin colonies: Hyaline, homogeneous, light brownish, contoured.
Gelatin stab: Liquefied.
Agar slant: Grayish, viscid, later with secondary colonies.
Broth: Turbid with pellicle and sediment.
Litmus milk.
Potato: No growth.
Growth on boiled fish: Moist, glistening, viscid, abundant, yellowish-gray.
Luminescence: Slight.
Aerobic, facultative.

Optimum temperature 15° to 20°C.

Habitat: Isolated from sea water along the coast near Sydney, Australia.

60. **Achromobacter granii** (Lundestad) Bergey et al. (*Bacterium granii* Lundestad, Cent. f. Bakt., II Abt., *75*, 1928, 330; Bergey et al., Manual, 3rd ed., 1930, 222.)

Rods with rounded ends, 0.6 to 0.8 by 1.4 to 2.4 microns, occurring singly, in pairs, and at times in short chains. Motile. Gram-negative.

Fish gelatin colonies: Punctiform, black, glistening.

Fish gelatin stab: Slow, crateriform liquefaction.

Sea-weed agar colonies: Circular, flat, opaque, glistening, white, slimy, entire. Agar is dissolved.

Fish-agar slant: Flat, white, elevated, glistening, undulate. Liquefied.

Broth: Turbid with grayish-white, slimy sediment.

Indol not formed.

Nitrates not reduced.

Starch usually hydrolyzed.

No action on carbohydrates.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Sea water of Norwegian Coast.

61. **Achromobacter pikowskyi** Bergey et al. (Culture No. 25, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 222.)

Rods, with rounded ends, 0.6 by 2.5 microns, with granular cytoplasm. Motile. Gram-negative.

Gelatin stab: Surface growth rose-colored. No liquefaction.

Agar colonies: Circular, transparent, opalescent, granular, with convex center.

Agar slant: Transparent streak.

Broth: Turbid, with grayish pellicle.

Litmus milk: Unchanged.

Potato: Grayish to rose-colored streak.

Indol formed.

Nitrates not reduced.

Ammonia formed.

H_2S not formed.

Growth occurs in media with 15 per cent NaCl.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Sea water.

62. **Achromobacter phosphoricum** (Migula) Bergey et al. (*Bacillus argenteo-phosphorescens III* Katz, Cent. f. Bakt., *9*, 1891, 157; *Bacillus phosphoricus* Migula, System der Bakterien, 1900, 870; Bergey et al., Manual, 3rd ed., 1930, 223.)

Rods: 0.4 to 0.5 by 2.5 microns, occurring singly, in pairs and in short chains. Motile. Gram-negative.

Gelatin colonies: Irregular, lobed, flat, whitish, furrowed.

Gelatin stab: No liquefaction.

Agar slant: Moderate, grayish.

Broth: Turbid with pellicle and sediment.

Potato: No growth.

Growth on boiled fish: Abundant, yellowish, moist, glistening.

Luminescence: Bluish-greenish-white.

Aerobic, facultative.

Optimum temperature 15° to 20°C.

Habitat: Isolated from *Sepia* obtained in fish market.

63. **Achromobacter galophilum** Bergey et al. (Culture No. 27, Baranik-Pikowsky, Cent. f. Bakt., II Abt., *70*, 1927, 373; Bergey et al., Manual, 3rd ed., 1930, 223.)

Rods: 0.3 to 1.0 by 1.3 to 2.5 microns, occurring singly, and in pairs, and in chains, with granular cytoplasm. Gram-negative.

Gelatin stab: No growth.

Agar slant: Grayish, glistening, opalescent, streak with undulate margin.

Broth: Slight turbidity, with thin pellicle.

Litmus milk: No growth.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Ammonia formed.

H_2S formed.

Grows in media with 25 per cent sea salt. Does not grow in media with less than 3 per cent NaCl.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Sea water.

64. **Achromobacter citrophilum** (Rubentschick) Bergey et al. (*Urobacterium citrophilum* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 168; *66*, 1926, 161; ibid., *67*, 1926, 167; ibid., *68*, 1826, 327; Bergey et al., Manual, 3rd ed., 1930, 224.)

Rods: 0.75 to 0.85 by 2.5 to 6.0 microns, occurring singly and in pairs. Spores not formed. Motile. Gram-positive.

Urea gelatin colonies: Small, grayish-white, smooth, undulate.

Urea gelatin stab: No liquefaction.

Urea agar colonies.

Urea agar slant: Filiform, grayish-white, thin, dry.

Urea broth: Turbid.

Urea milk: Unchanged.

Urea potato: Dirty-gray, thin streak.

Indol not formed.

Nitrates reduced to nitrites.
H_2S not formed.
Ammonia not formed.
Can derive oxygen from sodium citrate.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Sewage slime.

65. **Achromobacter aerophilum** (Rubentschick) Bergey et al. (*Urobacterium aerophilum* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 168; Bergey et al., Manual, 3rd ed., 1930, 224.)

Rods: 0.75 to 0.85 by 2.0 to 4.5 microns, occurring singly, in pairs, and in chains. Spores not formed. Motile. Gram-positive.
Urea gelatin colonies: Small, circular, dirty-gray, entire.
Urea gelatin stab: No liquefaction.
Urea agar colonies: Circular, grayish-smooth.
Urea agar slant: Dirty-gray, glistening to dry.
Urea broth: Turbid.
Urea milk: Unchanged.
Urea potato: Slight, grayish-white streak.
Indol not formed.
Nitrates reduced to nitrites.
H_2S not formed.
Ammonia not formed.
Aerobic, facultative.
Optimum temperature.
Habitat: Sewage slime

66. **Achromobacter amylovorum** (Rubentschick) Bergey et al. (*Urobacterium amylovorum* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 168; ibid., *66*, 1926, 161; Bergey et al., Manual, 3rd ed., 1930, 225.)

Rods: 0.8 to 0.95 by 2.5 to 6.0 microns, occurring singly, in pairs and in short chains. Spores not formed. Motile. Gram-negative.
Urea gelatin colonies: Circular, grayish-white, flat, homogeneous.
Urea gelatin stab: No liquefaction.
Urea agar colonies: Small, circular, grayish-white, entire.
Urea agar slant: Grayish-white streak, smooth, glistening.
Urea broth: Turbid.
Urea milk: Unchanged.
Urea potato: Dirty, grayish streak.
Indol not formed.
Nitrates not reduced.
Starch hydrolyzed.
H_2S not formed.
Ammonia not formed.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Sewage slime.

67. **Achromobacter smaragdinophosphorescens** (Katz) Bergey et al. (*Bacillus smaragdino-phosphorescens* Katz, Cent. f. Bakt., *9*, 1891, 157; *Bacterium smaragdino-phosphorescens* Migula, System der Bakterien, 1900, 435; Bergey et al., Manual, 3rd ed., 1930, 225.)

Rods: 1.0 by 2.0 microns with rounded ends, occurring singly and in pairs. Non-motile. Gram-positive.

Gelatin colonies: Circular, whitish-gray, thin, homogeneous to finely granular, moist, glistening.

Gelatin stab: Liquefied.

Agar slant: Grayish, viscid.

Broth: Turbid.

Litmus milk.

Potato: No growth.

Growth on boiled fish: Moderate, moist, glistening, cream-colored.

Luminescence: Approaches emerald green in color.

Aerobic: Facultative.

Optimum temperature 15° to 20°C.

Habitat: Isolated from herring in fish market in Sydney, Australia.

68. **Achromobacter globiforme** (Conn) Bergey et al. (*Bacterium globiformis* Conn, Tech. Bull. N. Y. Agr. Exper. Stat., No. 138, 1928; Bergey et al Manual, 3rd ed., 1930, 226.)

Short rods: 0.4 to 0.6 by 0.6 to 0.8 micron becoming coccoid in older cultures. Non-motile. Gram-positive, especially the coccoid forms.

Gelatin colonies: Circular, punctiform.

Gelatin stab: Slow crateriform liquefaction.

Agar colonies: Circular, punctiform, translucent.

Agar slant: Filiform, flat, smooth, soft, translucent, glistening, with characteristic sheen.

Broth: Slight growth.

Nitrates reduced to nitrites.

Dextrose, sucrose, mannitol, and less readily lactose and various organic acids are utilized as source of carbon and energy when grown in synthetic media.

Nitrogen may be obtained from ammonium sulphate, asparagin, cystin, glycocol, aspartic acid, uric acid, tyrosin, potassium nitrate, urea and peptone.

Aerobic, facultative.

Optimum temperature 22°C.

Habitat: Soil.

69. **Achromobacter luminosum** Bergey et al. (*Bacillus argenteo-phosphorescens II* Katz, Cent. f. Bakt., *9*, 1891, 157, *Bacterium argenteo-phosphorescens* Migula, System der Bakterien, 1900, 435; Bergey et al., Manual, 3rd ed., 1930, 226.)

Rods: 0.6 to 0.7 by 2.7 microns, occurring singly, in pairs and in short chains. Non-motile. Gram-negative.

Gelatin colonies: Circular, light yellowish, homogeneous, serrate margin.

Gelatin stab: No liquefaction.
Agar slant: Moderate, grayish.
Broth: Turbid.
Potato: No growth.
Growth on boiled fish: Abundant, yellowish to citron yellow, moist, glistening.
Luminescence: Greenish-silver.
Aerobic, facultative.
Optimum temperature 15° to 20°C.
Habitat: Isolated from fish obtained in market.

70. **Achromobacter nenckii** (Biernacki) Bergey et al. (*Bacterium nenckii* Biernacki, Cent. f. Bakt., II Abt., *29* 1911, 166; Bergey et al., Manual, 3rd ed., 1930, 227.)
Rods: 0.8 by 1.25 to 2.0 microns, with rounded ends, occurring singly and in pairs. Gram-negative.
Gelatin colonies: Circular, convex, yellowish-white, granular.
Gelatin stab: No liquefaction.
Agar colonies: Circular, grayish-white, glistening, concentric, finely granular.
Agar slant: The medium is liquefied.
Broth: Slightly turbid with gray sediment and slight odor.
Litmus milk: Acid and gas formation.
Potato: Slight growth.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, levulose, galactose, maltose, sucrose, raffinose and mannitol.
Fruity odor in cultures.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from Spanish dried grapes.

71. **Achromobacter larvae** (Stutzer and Wsorow) Bergey et al. (*Enterobacillus larvae* Stutzer and Wsorow, Cent. f. Bakt., II Abt., *71*, 1927, 119; Bergey et al., Manual, 3rd ed., 1930, 227.)
Rods: 0.5 by 1.0 to 1.5 microns. Non-motile. Gram-negative.
Gelatin colonies.
Gelatin stab: Not liquefied.
Agar colonies: Small, circular, transparent, weakly opalescent, undulate margin, rugose.
Agar slant.
Broth: Turbid.
Litmus milk: Not coagulated.
Potato.
Indol formed.

Acid in dextrose.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 20°C
Habitat: Intestinal tract of normal caterpillars.

72. **Achromobacter eurydice** (White) Bergey et al. (*Bacterium eurydice* White, U. S. Dept. of Agr., Bur. of Entomol., Circ. 157, 1912, 3; Bergey et al., Manual, 2nd ed., 1927, 170.)

Rods, small, slender, with slightly rounded ends, occurring singly and in pairs. Non-motile. Does not form spores. Gram-negative.

Gelatin stab: A bluish gray growth occurs along the line of inoculation. No liquefaction.

Glucose agar colonies: Bluish gray, circular, smooth, glistening, entire.
Broth: Uniform turbidity with viscid sediment.
Litmus milk: Unchanged.
Potato: Slight, grayish growth.
Aerobic, facultative.
Habitat: Occurs as a secondary invader in European "foulbrood" of bees.

73. **Achromobacter candicans** (Frankland and Frankland) Bergey et al. (*Bacillus candicans* G. and P. Frankland, Zeitschr. f. Hyg., *6*, 1889, 397; Bergey et al., Manual, 1st ed., 1923, 149.)

Rods: 0.5 to 0.6 by 0.75 to 1.2 microns, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: White, moist, glistening, entire.
Gelatin stab: White surface growth, becoming light reddish in color. No liquefaction.
Agar colonies: Circular, white, entire.
Agar slant: Thin, grayish-white, transparent, becoming opaque, entire.
Broth: Turbid, with gray flocculent pellicle and sediment.
Litmus milk: Becoming alkaline.
Potato: Thick, gray, slimy.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Soil.

74. **Achromobacter connii** (Chester) Bergey et al. (Culture No. 55, Conn, Storrs Agr. Exper. Sta., 1894, 83; *Bacterium connii* Chester, Determinative Bacteriology, 1901, 146; Bergey et al., Manual, 1st ed., 1923, 149.)

Rods: 0.8 by 1.0 micron, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: White, granular, spreading, entire.
Gelatin stab: Surface growth thin, translucent, spreading. No liquefaction.

Agar slant: White, smooth, spreading.
Broth: Clear, with flaky sediment.
Litmus milk: Becoming alkaline.
Potato: Raised, yellowish, spreading.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 25° to 30°C.
Habitat: Milk.

75. **Achromobacter refractans** (Wright) Bergey et al. (*Bacillus refractans* Wright, Memoirs Nat. Acad. Sci., *7*, 1894, 442; *Bacterium refractans* Chester, Determinative Bacteriology, 1901, 139; Bergey et al., Manual, 1st ed., 1923, 150.)

Short, medium-sized rods, occurring singly and in pairs. Non-motile. Gram-negative.
Gelatin colonies: Small, white, raised, smooth.
Gelatin stab: White, wrinkled surface growth. No liquefaction.
Agar slant: Thin, narrow, translucent.
Broth: Slightly turbid, with slight pellicle and sediment.
Litmus milk: Becoming alkaline.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Water.

76. **Achromobacter tiogense** (Wright) Bergey et al. (*Bacillus tiogensis* Wright, Memoirs Nat. Acad. Sci., *7*, 1894, 441; *Bacterium tiogense* Chester, Determinative Bacteriology, 1901, 139; Bergey et al., Manual, 1st ed., 1923, 150.)

Medium-sized rods, plump, occurring singly, in pairs and in chains. Non-motile. Gram-negative.
Gelatin colonies: White, circular, raised.
Gelatin stab: White surface growth. No liquefaction.
Agar slant: Grayish, glistening, limited.
Broth: Turbid.
Litmus milk: Alkaline; litmus reduced.
Potato: Grayish-brown, spreading.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 20° to 25°C.
Habitat: Water.

77. **Achromobacter rodonatum** (Ravenel) Bergey et al. (*Bacillus rodonatus* Ravenel, Memoirs Nat. Acad. Sci., *8*, 1896, 40; Bergey et al., Manual, 1st ed., 1923, 150.)

Short, oval rods, with rounded ends, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Grow slowly, rosette-form, becoming petaloid along border; center reddish-brown, border yellowish-gray.

Gelatin stab: Thin, irregular, leaf-like surface growth. No liquefaction.

Agar slant: Thin, white, translucent, limited.

Broth: Turbid, with thin pellicle.

Litmus milk: Alkaline; litmus reduced.

Potato: Yellowish-brown, moist, glistening.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Soil.

78. **Achromobacter aromafaciens** (Chester) Bergey et al. (Bacillus No. 41, Conn, Storrs Agr. Expr. Sta., 1894, 57; *Bacterium aromafaciens* Chester, Determinative Bacteriology, 1901, 148; Bergey et al., Manual, 1st ed., 1923, 151.)

Rods: 1.0 by 6.0 microns, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Very small, gray.

Gelatin stab: Surface growth moist, white, convex, entire. No liquefaction.

Agar slant: White, glistening.

Broth: Turbid, with gray pellicle.

Litmus milk: Slightly acid; slow peptonization.

Potato: White to yellow, raised.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Milk.

79. **Achromobacter middletownii** (Chester) Bergey et al. (Culture No. 53, Conn, Storrs Agr. Expr. Sta., 1894, 82; *Bacterium middletownii* Chester, Determinative Bacteriology, 1901, 147; Bergey et al., Manual, 1st ed., 1923, 151.)

Short rods, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, raised.

Gelatin stab: White, slightly spreading surface growth. No liquefaction.

Agar slant: White, raised.

Broth: Slightly turbid, with gray sediment.

Litmus milk: Acid.

Potato: Whitish, becoming brownish.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Milk.

80. **Achromobacter acidum** (Chester) Bergey et al. (Culture No. 56, Conn, Storrs Agr. Expr. Sta., 1894, 83; *Bacterium acidum* Chester Determinative Bacteriology 1901, 146; Bergey et al., Manual, 1st ed., 1923, 151.)

Rods: 0.8 by 1.0 micron, occurring singly, in pairs and in chains. Non-motile. Gram-negative.
Gelatin colonies: Large, thin, white, translucent, lobate.
Gelatin stab: Thin surface growth. No liquefaction.
Agar slant: Thin, white, spreading.
Broth: Slightly turbid, with white sediment.
Litmus milk: Acid.
Potato: Limited, gray.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Milk.

81. **Achromobacter lacticum** (Kramer) Bergey et al. (*Bacterium lacticum* Kramer, Die Bakteriologie der Landwirtschaft, 1892, 24; Bergey et al., Manual, 1st ed., 1923, 152.)

Short, rather thick rods, occurring singly, in pairs and in chains. Non-motile. Gram-negative.
Gelatin colonies: Circular, gray, entire to erose.
Gelatin stab: No liquefaction.
Agar slant: Dirty-white, isolated colonies.
Broth: Turbid.
Litmus milk: Acid, slimy.
Potato: Rather dry, grayish-white.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Milk.

82. **Achromobacter coccoideum** (Chester) Bergey et al. (Culture No. 16, Conn, Storrs Agr. Expr. Sta., Conn, 1894, 51; *Bacterium coccoideum* Chester, Determinative Bacteriology, 1901, 147; Bergey et al., Manual, 1st ed., 1923, 152.)

Oval to coccoid forms, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: Thin, white, spreading.
Gelatin stab: White surface growth. No liquefaction.
Agar slant: Thin, white, glistening, spreading.
Broth: Turbid.
Litmus milk: Acid; coagulation; peptonization. Gas is formed.

Potato: Thin, dirty-white, spreading.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Milk.

83. **Achromobacter fermentationis** (Chester) Bergey et al. (*Bacterium fermentationis* Chester, Report, Del. Agr. Exper. Sta., 1899, 53; Bergey et al., Manual, 1st ed., 1923, 152.)

Rods: 0.8 by 1.25 to 3.0 microns, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: Small, dull white, flat, moist, glistening.
Gelatin stab: Thin, flat surface growth. No liquefaction.
Agar colonies: Circular, white, slightly convex, moist, somewhat translucent.
Agar slant: Flat, opaque, moist, glistening.
Broth: Turbid, with slight, gray sediment.
Litmus milk: Acid; coagulated.
Potato: Thick, white, moist, glistening, becoming dirty-brown.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil.

84. **Achromobacter ubiquitum** (Jordan) Bergey et al. (*Bacillus ubiquitus* Jordan, Report Mass. State Bd. of Health, 1890, 830; Bergey et al., Manual, 1st ed., 1923, 153.)

Rods: 1.0 by 1.1 to 2.0 microns, occurring singly, in pairs and in short chains. Non-motile. Gram-negative.
Gelatin colonies: Gray, circular, entire to irregular margin.
Gelatin stab: No liquefaction.
Agar colonies: Grayish-white, with slight metallic luster.
Agar slant: Whitish-gray layer.
Broth: Turbid, with gray pellicle.
Litmus milk: Acid; coagulated.
Potato: White, slimy, spreading.
Indol not formed.
Nitrates reduced to nitrites.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Water.

85. **Achromobacter filifaciens** (H. Jensen) Bergey et al. (*Bacterium filifaciens* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 401; Bergey et al., Manual, 1st ed., 1923, 153.)

Rods: 0.5 to 0.7 by 0.5 to 1.5 microns, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: Thin, flat, slimy, becoming moist, glistening.
Gelatin stab: White, slimy surface growth. No liquefaction.
Agar colonies: Moist, glistening, dirty-grayish, slimy.
Agar slant: Moist, grayish, glistening, slimy, with raised center.
Broth: Turbid.
Litmus milk: Acid; coagulated.
Potato: Dirty-white, slimy layer.
Indol not formed.
Nitrates reduced to nitrogen.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Air.

86. **Achromobacter nitrovorum** (H. Jensen) Bergey et al. (*Bacterium nitrovorum* H. Jensen, Cent. f. Bakt., II Abt., *4*, 1898, 450; Bergey et al., Manual, 1st ed., 1923, 154.)
Rods: 0.5 by 0.5 by 1 0 micron, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: White, slimy, entire.
Gelatin stab: White, moist, glistening surface growth. No liquefaction.
Agar colonies: Grayish-white, slimy.
Agar slant: Grayish, moist, slimy, entire.
Broth: Turbid.
Litmus milk: Acid; coagulated.
Potato: Dirty-white, slimy.
Indol not formed.
Nitrates reduced to nitrogen.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Horse manure.

TRIBE V. ERWINIEAE COMMITTEE S. A. B., 1920.

Plant pathogens. Invade the tissues of plants and produce local lesions; some species killing the host plants. Morphologic and cultural characters vary in different species.

Key to genera of tribe **Erwinieae.**

1. Motile rods. Flagella peritrichous.
   Genus VIII. *Erwinia*, p. 248.
2. Rods motile or non-motile. Motile forms possess polar flagella.
   Genus IX. *Phytomonas*, p. 254.

Genus VIII. Erwinia Winslow et al., *1917.*

Motile rods, possessing peritrichous flagella. The rods are white, and growth usually is white, although a few species form pigment.
The type species is *Erwinia amylovora* (Burrill) Winslow et al., 1920.

Key to the species of genus **Erwinia.**

1. Gelatin liquefied.
    a. No pigment formed.
    b. Milk slowly coagulated.
    c. Nitrates not reduced.
        1. *Erwinia amylovora.*
    bb. Milk coagulated with gas formation.
    c. Nitrates reduced.
    d. Starch not hydrolyzed.
        2. *Erwinia melonis.*
    dd. Starch hydrolyzed.
        3. *Erwinia solanisapra.*
        4. *Erwinia carotovora.*
        5. *Erwinia aroidea.*
        6. *Erwinia oleracea.*
        7. *Erwinia cypripedii.*
    aa. Yellowish-brown pigment formed.
    b. Milk acid coagulated.
    c. Nitrates reduced.
    d. Starch hydrolyzed.
        8. *Erwinia phytophthora.*
    bb. Milk acid; coagulated, becoming alkaline.
    c. Nitrates reduced.
    d. Starch hydrolyzed.
        9. *Erwinia nicotianae.*
    cc. Nitrates not reduced.
    d. Starch not hydrolyzed.
        10. *Erwinia mangiferae.*
        11. *Erwinia erivanensis.*
2. Gelatin not liquefied.
    a. No pigment formed.
    b. Milk unchanged.
    c. Nitrates not reduced.
    d. Starch not hydrolyzed.
        12. *Erwinia tracheiphila.*

1. **Erwinia amylovora** (Burrill) Winslow et al. (*Micrococcus amylovorus* Burrill, American Naturalist, 7, 1882, 319; *Bacillus amylovorus* Trevisan, I gen. e le spec. delle batteriacee, 1889, 19; *Bacterium amylovorum* Chester, Manual Determ. Bact., 1901, 176; Winslow et al., Jour. Bact., *5*, 1920, 209.)

Rods: 0.7 to 1.0 by 0.9 to 1.5 microns, occurring singly and in pairs. Motile with several peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, amorphous, light grayish-brown, entire.

Gelatin stab: Thin, whitish, dry, glistening surface growth. Later crateriform liquefaction.

Agar colonies: Circular, raised, glistening, grayish-white, irregular margin.

Agar slant: Moist, white, glistening, butyrous, becoming pinkish or flesh color.

Broth: Turbid, with thin, granular pellicle.

Litmus milk: Reaction unchanged. A soft curd is slowly formed.

Indol not formed.

Nitrates not reduced.

No gas in carbohydrate media.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: The causative agent of "blight" in pear and apple trees.

2. **Erwinia melonis** (Geddings) Holland. (*Bacillus melonis* Geddings, Vermont Agr. Exp. Sta. Bull. 148, 1910, 413; Holland, Jour. Bact., *5*, 1920, 215.)

Rods: 0.6 to 0.9 by 1.0 to 1.7 microns with rounded ends, occurring singly. Motile with four to six peritrichous flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: Rapid, infundibuliform liquefaction.

Agar colonies: Circular or amoeboid.

Agar slant: Gray, slimy, glistening, translucent.

Broth: Turbid, with slight grayish sediment. No pellicle formed.

Litmus milk: Coagulation with gas formation.

Potato.

Slight amount of indol formed.

Nitrates reduced to nitrites.

Gas in lactose media.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: The cause of "soft rot" in muskmelon, citron, cucumber, potato, carrot, beet, turnip.

3. **Erwinia solanisapra** (Harrison) Holland. (*Bacillus solanisaprus* Harrison, Cent. f. Bakt., II Abt., *17*, 1907, 34; Holland, Jour. Bact., *5*, 1920, 215.)

Rods with rounded ends: 0.6 to 0.9 by 1.5 to 4.0 microns, occurring singly. Motile with five to fifteen peritrichous flagella. Gram-negative.

Gelatin colonies: Very small, barely visible to the naked eye; when magnified, they are circular, hyaline, brownish, entire.

Gelatin stab: Flat, whitish surface growth. Slow liquefaction.

Agar colonies: Small, grayish-white, flat, slimy, very finely granular, entire.

Agar slant: Slightly elevated, moist, glistening, opalescent.

Broth: Turbid, with thin pellicle and fine sediment.

Litmus milk: Coagulated after 48 hours with slight acid reaction and a few gas bubbles.

Potato: Raised, spreading, dull, waxy, pale cream color.

Raw potato: White rot, devoid of smell and very rapid.

Indol not produced.

Nitrates reduced to nitrites.

Gas in lactose and mannitol media.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 25° to 28°C. Thermal death point 55°C. for 10 minutes.

Habitat: The cause of "soft rot" in potato, causing dark green to blackening of stem. Pathogenic for tomato, peppers, etc.

4. **Erwinia carotovora** (Jones) Holland. (*Bacillus carotovorus* Jones' Cent. f. Bakt., II Abt., *7*, 1901, 12; Holland, Jour. Bact., *5*, 1920, 222.)

Rods: 0.7 to 0.8 by 1.5 to 5.0 microns, with rounded ends, occurring singly and in long chains. Motile with two to five peritrichous flagella. The rods are grayish-white. Gram-negative.

Gelatin stab: Slow, crateriform to infundibuliform liquefaction.

Agar colonies: Circular, white, smooth, entire to undulate margin, homogeneous to granular.

Agar slant: Filiform to spreading, white, glistening, opaque to opalescent.

Broth: Turbid, with pellicle and white flocculent sediment.

Litmus milk: Coagulated with acid reaction and a few gas bubbles.

Potato: Thick, creamy-white, the medium becoming softened.

Slight amount of indol formed.

Nitrates reduced to nitrites.

Gas in dextrose, lactose, sucrose and mannitol media, the gas being 20 per cent CO_2 and 80 per cent H_2.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: The cause of "soft rot" in carrots and other plants.

5. **Erwinia aroidea** (Townsend) Holland. (*Bacillus aroideus* Townsend, Bull. 60, Bureau of Plant Industry, Dept. of Agr., Washington, D. C., 40; Holland, Jour. Bact., *5*, 1920, 222.)

Harding and Morse (N. Y. Agr. Exp. Sta., Tech. Bul. No. 11, 1909) believe this organism to be identical with *Erwinia carotovora.*

Habitat: Causes "soft rot" in calla.

6. **Erwinia oleracea** (Harrison) Bergey et al. (*Bacillus oleraceus* Harrison, Cent. f. Bakt., II Abt., *13*, 1904, 46; Bergey et al., Manual, 1st ed., 1923, 171.)

Harding and Morse (loc. cit.) believe this organism to be identical with *Erwinia carotovora*.

Habitat: Causes "soft rot" in cauliflower, cabbage and turnips.

7. **Erwinia cypripedii** (Hori) Bergey et al. (*Bacillus cypripedii* Hori, Centralbl. f. Bakt., II Abt., *31*, 1911, 85; Bergey et al., Manual, 1st ed., 1923, 171.)

Rods: 0.5 to 0.7 by 1.5 to 2.0 microns, with rounded ends. Motile with four peritrichous flagella. Gram-positive.

Gelatin colonies: Grayish-white, irregularly circular.

Gelatin stab: White, toruloid surface growth. Slow liquefaction.

Agar colonies: Grayish-white, transparent, entire.

Agar slant: Light grayish, thin, serrate to fimbriate margin.

Broth: Turbid, with thin pellicle.

Litmus milk: Coagulated, with gas formation.

Potato: Cream color, raised, smooth, slimy, undulate.

Indol not formed.

Nitrates are reduced to nitrites.

Acid and gas in dextrose and lactose.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Isolated from leaf-disease of tropical orchids.

8. **Erwinia phytophthora** (Appel) *comb. nov.* (*Bacillus phytophthorus* Appel, Ber. d. deutsch. Bot. Gesel., *20*, 1902, 129; *Bacillus atrosepticus* van Hall, Inaug. Dissert., Amsterdam, 1902; *Bacillus melanogenes* Pethybridge and Murphy, Proc. Roy. Irish Acad., *29*, B, No. 1, 1911; *Erwinia atroseptica* Bergey et al., Manual, 1st ed., 1923, 172.)

Rods: 0.6 to 0.8 by 1.25 to 2.5 microns. Actively motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Large, circular, opaque, white, fringed, liquefying.

Gelatin stab: Rapid, infundibuliform liquefaction.

Agar colonies: Circular, smooth, grayish-white.

Agar slant: Grayish-white.

Broth: Turbid.

Litmus milk: Coagulated, with acid reaction.

Potato: White, slimy growth, with darker, yellowish border. The medium becomes softened.

Indol not formed.

Nitrates reduced to nitrites.

Acid and gas in carbohydrate media.

Starch is hydrolyzed.

Raw potato: Pink color and black (melarin) margin.

Odor of trimethylamine.

pH 7.2 of rotted juice.

Aerobic, facultative.

Optimum temperature 28° to 30°C. Thermal death point 47°C. for 10 minutes.

Habitat: The cause of stem rot (black leg) in potato, also affects cucumbers and other vegetables.

9. **Erwinia nicotianae** (Uyeda) Bergey et al. (*Bacillus nicotianae* Uyeda, Bull. Imp. Cent. Agr. Exp. Sta., Japan, 1905, 39; Cent. f. Bakt., II Abt., *13*, 1904, 327; Bergey et al., Manual, 1st ed., 1923, 172.)

Rods: 0.5 to 0.7 by 1.0 to 1.2 microns, with rounded ends, occurring singly and occasionally in pairs. Motile with four to eight peritrichous flagella. Encapsulated. Gram-negative.

Gelatin colonies: Small, gray, circular.

Gelatin stab: Slow, saccate, liquefaction.

Agar colonies: Circular, dirty-white, becoming brown with concentric rings. Medium becomes brown in vicinity of colonies.

Agar slant: Moist, grayish, glistening, slimy.

Broth: Turbid, with thin pellicle, with black ring (in a month). Slight sediment.

Litmus milk: Acid, coagulated, peptonized, becoming greenish. Later slightly alkaline.

Potato: Yellow growth, becoming brown to black. The medium softens and becomes darker. Tyrosinase formed.

Slight indol formation.

Nitrates reduced to nitrites.

Acid and gas in dextrose media.

Starch hydrolyzed.

Aerobic, facultative.

Optimum temperature 32°C.

Habitat: Isolated from tobacco plants affected with wilt.

10. **Erwinia mangiferae** (Doidge) Bergey et al. (*Bacillus mangiferae* Doidge, Annals of Applied Biology, *2*, 1915, 1–45; Bergey et al., Manual, 1st ed., 1923, 173.)

Rods with rounded ends: 0.6 by 1.5 microns, occurring singly and in chains. Motile with two to eight peritrichous flagella. Encapsulated. Gram-negative.

Gelatin colonies.

Gelatin stab: Liquefied.

Agar colonies: Yellow, shiny.

Agar slant: Yellow, shiny.

Broth: Turbid, with yellow ring.

Litmus milk: Slow coagulation.

Potato: Shiny, yellow, spreading.

Indol not formed.

Nitrates not reduced.

Blood serum not liquefied.

Starch not hydrolyzed.

Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Causes disease of the mango.

11. **Erwinia erivanensis** (Kalantorian) Bergey et al. (*Bacterium erivanense* Kalantorian, Cent. f. Bakt., II, *65*, 1925, 298; Bergey et al., Manual, 3rd ed., 1930, 239.)

Rods with rounded ends, 0.5 to 0.7 by 1.25 to 2.5 microns. Motile with peritrichous flagella. Gram-negative.
Gelatin colonies: Circular, gray, entire.
Gelatin stab: Slowly liquefied. Yellow sediment.
Agar colonies: Circular, white.
Agar slant: Grayish, white, slimy.
Broth: Turbid with flocculent sediment.
Litmus milk: Coagulation. Peptonized. Alkaline.
Potato: Yellow, raised, dull.
Indol formed.
Nitrates not reduced.
Acid and gas in dextrose, sucrose and mannitol.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Root rot of cotton plant.

12. **Erwinia tracheiphila** (Erw. Smith) Holland. (*Bacillus tracheiphilus* Erw. Smith, Bacteria in Relation to Plant Diseases, *2*, 1911, 286, Holland, Jour. Bact. *5*, 1920, 215.)

Rods: 0.5 to 0.7 by 1.2 to 2.5 microns, occurring singly and in pairs. The organisms are white in the plant and show a capsule. Motile with four to eight peritrichous flagella. Gram-negative.
Gelatin colonies: Thin, grayish-white, slimy.
Gelatin stab: Thin, smooth, white, slimy.
Agar slant: Gray, smooth, filiform.
Broth: Slightly turbid. No pellicle.
Litmus milk: Unchanged.
Potato: White, barely visible, slimy.
Indol not formed.
Nitrates not reduced.
Acid but no gas in dextrose, sucrose and glycerol.
Starch not hydrolyzed.
Optimum temperature 30°C.
Habitat: The causative organism of cucumber wilt, affecting also cantaloupes, muskmelons, pumpkins and squashes.

Genus IX. Phytomonas *Bergey et al., 1923.*

Rods, yellow or white, motile or non-motile, the motile species possessing either mono- or lophotrichous flagella. May or may not form yellow pigment. The type species is *Phytomonas campestris* (Pammel) Bergey et al.

Key to the species of genus **Phytomonas.**

I. Motile rods.
A. Rods yellow.
1. Yellow pigment formed.
a. Gelatin liquefied.
b. Milk coagulated, becoming alkaline.
c. Nitrates not reduced.
d. Starch hydrolyzed.
1. *Phytomonas campestris.*
2. *Phytomonas phaseoli.*
3. *Phytomonas malvacearum.*
4. *Phytomonas hyacinthi.*
bb. Milk acid; coagulated.
c. Nitrates not reduced.
d. Starch hydrolyzed.
5. *Phytomonas flaccumfaciens.*
6. *Phytomonas proteamaculans.*
7. *Phytomonas juglandis.*
aa. Gelatin not liquefied.
b. Milk alkaline.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
8. *Phytomonas vascularum.*
cc. Nitrates reduced.
d. Starch not hydrolyzed.
9. *Phytomonas tritici.*
2. No pigment formed.
a. Gelatin not liquefied.
b. Milk slowly coagulated.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
10. *Phytomonas pruni.*
bb. Milk unchanged.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
11. *Phytomonas medicaginis.*
AA. Rods white.
1. Yellow pigment formed.
a. Gelatin liquefied.
b. Milk coagulated.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
12. *Phytomonas xanthochlora.*
13. *Phtyomonas gummisudans.*
dd. Starch hydrolyzed.
14. *Phytomonas citri.*
15. *Phytomonas pelargoni.*

cc. Nitrates reduced.

16. *Phytomonas papavericola.*

bb. Milk slightly acid.

c. Nitrates not reduced.

d. Starch hydrolyzed.

17. *Phytomonas campestris* var. *armoraciae.*

18. *Phytomonas cucurbitae.*

dd. Starch not hydrolyzed.

19. *Phytomonas translucens.*

bbb. Milk alkaline.

c. Nitrates reduced.

d. Starch hydrolyzed.

20. *Phytomonas marginalis.*

dd. Starch not hydrolyzed.

21. *Phytomonas beticola.*

cc. Nitrates not reduced.

d. Starch hydrolyzed.

22. *Phytomonas vesicatora.*

23. *Phytomonas vitians.*

24. *Phytomonas mellea.*

bbbb. Milk peptonized.

25. *Phytomonas holicicola.*

aa. Gelatin not liquefied.

b. Milk alkaline.

c. Nitrates reduced.

d. Starch not hydrolyzed.

26. *Phytomonas amaranthi.*

27. *Phytomonas solanacearum.*

cc. Nitrates not reduced.

d. Starch not hydrolyzed.

28. *Phytomonas woodsii.*

29. *Phytomonas glycinea.*

2. Fluorescent pigment formed.

a. Gelatin liquefied.

b. Milk coagulated; becoming alkaline.

c. Nitrates not reduced.

30. *Phytomonas erodii.*

d. Starch not hydrolyzed.

31. *Phytomonas syringae.*

32. *Phytomonas citriputealis*

33. *Phytomonas trifoliorum.*

34. *Phytomonas atrofaciens.*

35. *Phytomonas holci.*

36. *Phytomonas tolaasi.*

cc. Nitrates reduced.
d. Starch not hydrolyzed.
37. *Phytomonas bowlesii.*
bb. Milk not coagulated; alkaline.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
38. *Phytomonas viridilivida.*
39. *Phytomonas vignae.*
40. *Phytomonas delphinii.*
bbb. Milk slightly acid.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
41. *Phytomonas pseudozoogloeae.*
42. *Phytomonas cerasi.*
43. *Phytomonas martyniae.*
aa. Gelatin not liquefied.
b. Milk peptonized.
c. Nitrates not reduced.
44. *Phytomonas nectarophila.*
3. No pigment formed on gelatin or agar.
a. Gelatin liquefied.
b. Milk acid; peptonized.
c. Nitrates reduced.
d. Starch not hydrolyzed.
45. *Phytomonas marginata.*
46. *Phytomonas avenae.*
47. *Phytomonas hibisci.*
dd. Starch hydrolyzed.
48. *Phytomonas destructans.*
cc. Nitrates not reduced.
d. Starch hydrolyzed.
49. *Phytomonas barkeri.*
bb. Milk coagulated.
c. Nitrates not reduced.
d. Starch hydrolyzed.
50. *Phytomonas coronafaciens.*
51. *Phytomonas pisi.*
52. *Phytomonas matthiolae.*
bbb. Milk peptonized; becoming alkaline.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
53. *Phytomonas angulata.*
54. *Phytomonas papulans.*
dd. Starch hydrolyzed.
55. *Phytomonas puerariae.*

bbbb. Milk alkaline.
c. Nitrates reduced.
d. Starch hydrolyzed.
56. *Phytomonas cannae.*
57. *Phytomonas striafaciens.*
cc. Nitrates not reduced.
d. Starch hydrolyzed.
58. *Phytomonas lachrymans.*
59. *Phytomonas panici.*
dd. Starch not hydrolyzed.
60. *Phytomonas apii.*
61. *Phytomonas aptata.*
62. *Phytomonas tabaci.*
63. *Phytomonas maculicola.*
bbbbb. Milk not coagulated; clearing.
c. Nitrates reduced.
d. Starch not hydrolyzed.
64. *Phytomonas seminum.*
dd. Starch hydrolyzed.
65. *Phytomonas rubrilineans.*
66. *Phytomonas intybi.*
aa. Gelatin not liquefied.
b. Milk slowly coagulated.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
67. *Phytomonas tumefaciens.*
68. *Phytomonas solaniolens.*
69. *Phytomonas cichori.*
cc. Nitrates reduced.
70. *Phytomonas dissolvens.*
bb. Milk alkaline.
c. Nitrates not reduced.
d. Starch hydrolyzed.
71. *Phytomonas savastonoi.*
72. *Phytomonas mori.*
73. *Phytomonas andropogoni.*
74. *Phytomonas loehnisii.*
dd. Starch not hydrolyzed.
75. *Phytomonas sojae.*
cc. Nitrates reduced.
d. Starch hydrolyzed.
76. *Phytomonas alboprecipitans.*
aaa. Gelatin not given.
77. *Phytomonas rhizogenes.*

II. Non-motile rods.
a. Gelatin liquefied.
b. Milk slowly coagulated.
c. Nitrates not reduced.
d. Starch not hydrolyzed.
78. *Phytomonas michiganensis.*
bb. Milk alkaline.
79. *Phytomonas insidiosa.*
aa. Gelatin not liquefied.
b. Milk acid; becoming alkaline.
c. Nitrates not reduced.
d. Starch hydrolyzed.
80. *Phytomonas stewartii.*
dd. Starch not hydrolyzed.
81. *Phytomonas rathayi.*
82. *Phytomonas stizolobii.*
bb. Milk unchanged.
83. *Phytomonas teutlia.*
bbb. Milk slightly coagulated.
84. *Phytomonas agropyri.*

1. **Phytomonas campestris** (Pammel) Bergey et al. (*Bacillus campestris* Pammel, Iowa Agr. Exp. Sta., Bull. No. 27, 1895, 130; *Pseudomonas campestris* Erw. Smith, Cent. f. Bakt., II Abt., 3, 1897, 284; *Bacterium campestre* Erw. Smith, Bacterial Diseases of Plants, *2*, 1911, 316; Bergey et al., Manual, 1st ed., 1923, 176.)

Rods: 0.4 to 0.5 by 0.7 to 3.0 microns, occurring singly and in long chains in old cultures. Without capsule. Motile, with a single polar flagellum. Rods are yellow in the plant. Gram-negative.

Gelatin colonies: Circular, pale yellow, slightly raised center, becoming deeper yellow with age. Slowly liquefied.

Agar colonies: Thin, flat, pale yellow, circular, entire, with slight tendency to form concentric rings.

Agar slant: Pale yellow growth.

Broth: Turbid, with yellow ring.

Litmus milk: Slow coagulation, with alkaline reaction.

Potato: Copious, yellow, slimy layer.

Slight indol formation.

Nitrates not reduced.

No acid in carbohydrate media.

Starch is hydrolyzed.

Produces brown pigment soluble in water and yellow pigment soluble in glycerol, ethyl and methyl alcohol, acetone, ammonium carbonate solution and glacial acetic acid.

Aerobic, facultative.

Optimum temperature 25° to 30°C.
Habitat: Associated with "black rot" of cruciferous plants.

2. **Phytomonas phaseoli** (Erw. Smith) Bergey et al. (*Bacterium phaseoli* Erw. Smith, Proc. Amer. Assoc. Adv. Sci., 1898, 288; *Bacillus phaseoli* Erw. Smith, U. S. Dept. Agr. Div. Veg. Phys. and Path., Bul. 28, 1901; *Pseudomonas phaseoli* Erw. Smith, U. S. Dept. Agr. Div. Veg. Phys. and Path., Bul. 28, 1901; Bergey et al., Manual, 1st ed., 1923, 177.)

Short rod, yellow, with rounded ends, 0.45 to 1.35 by 1.35 to 3.6 microns, occurring singly and in pairs. Motile with a polar flagellum. Gram-negative.

Gelatin colonies.
Gelatin stab: Fairly rapid liquefaction.
Agar colonies: Small, pale yellow, circular, smooth, glistening, entire, becoming deep yellow.
Agar slant: Pale yellow, smooth, moist, glistening, entire.
Broth: Turbid.
Litmus milk: Slowly coagulated, becoming alkaline, clearing, with yellow surface growth and sediment.
Potato: Digested.
Indol not formed.
Nitrates not reduced.
No acid in sugar media.
Starch is hydrolyzed.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Associated with "blight" in beans and in related plants.

3. **Phytomonas malvacearum** (Erw. Smith) Bergey et al. (*Pseudomonas malvacearum* Erw. Smith, U. S. Dept. Agr. Div. Veg. Phys. and Path., Bul. 28, 1901, 153; *Bacterium malvacearum* Erw. Smith, Bacteria in relation to plant diseases, *1*, 1905, 171; Bergey et al., Manual, 1st ed., 1923, 178.)

Rods yellow, occurring singly. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Circular, yellow.
Gelatin stab: Slowly liquefied.
Agar colonies: Circular, very pale yellow, flat, thin, smooth, showing a radiate structure.
Agar slant.
Broth: Turbid, with a pale yellow ring and moderate yellow sediment.
Litmus milk: Coagulated. Litmus reduced. Alkaline.
Potato: Thin, pale yellow to wax yellow to brownish.
Indol not formed.
Nitrates not reduced.
No acid in sugar media.
Starch is hydrolyzed.
Aerobic, facultative.

Optimum temperature 25° to 30°C.
Habitat: The cause of "angular leaf spot" of cotton plants.

4. **Phytomonas hyacinthi** (Wakker) Bergey et al. (*Bacterium hyacinthi* Wakker, Botan. Centralblatt, *14*, 1883, 315; *Bacillus hyacinthi* Trevisan, I generi e le specie delle batteriacee, 1889, 19; *Pseudomonas hyacinthi* Erw. Smith, Bot. Gazette, *24*, 1897, 188; Bergey et al., Manual, 1st ed., 1923, 177.)

Bright yellow rods: 0.4 to 0.6 by 0.8 to 2.0 microns, with rounded ends, occurring singly and in pairs. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Circular, smooth, pale yellow, moist, glistening.
Gelatin stab: Slow, stratiform liquefaction.
Agar colonies: Like gelatin colonies.
Agar slant: Dry, wrinkled, feeble.
Broth: Feeble growth.
Litmus milk: Slow coagulation, becoming alkaline with yellow ring.
Potato: Moderate, smooth, wax-yellow, becoming dull, brownish-yellow.
Indol is formed.
Nitrates not reduced.
No gas in carbohydrate media.
Blood serum slowly peptonized.
Starch is hydrolyzed.
H_2S is formed.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: In yellow slime disease of *Hyacinthus orientalis*.

5. **Phytomonas flaccumfaciens** (Hedges) Bergey et al. (*Bacterium flaccumfaciens* Hedges, Science, N. S., *55*, 1922, 433; Bergey et al., Manual, 1st ed., 1923, 178; *Pseudomonas flaccumfaciens* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 164.)

Short yellow rods: 0.6 to 1.5 by 0.9 to 2.7 microns, occurring singly and in pairs. Motile with a polar flagellum. Gram-negative.

Gelatin stab: Slowly liquefied.
Agar colonies: Circular, yellow.
Agar slant: Filiform, smooth, yellow.
Broth: Turbid.
Litmus milk: Acid with slow coagulation and peptonization. Litmus reduced. No tyrosin crystals formed.
Potato: Scant, primulin-yellow growth, the medium becoming gray.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, maltose, lactose and sucrose
Starch shows slight hydrolysis.
Aerobic, facultative.

Optimum temperature.
Habitat: Causes wilt disease in navy bean.

6. **Phytomonas proteamaculans** (Paine and Stansfield) Bergey et al. (*Pseudomonas proteamaculans* Paine and Stansfield, Ann. Appl. Biol., *6*, 1919, 27; Bergey et al., Manual, 3rd ed., 1930, 247; *Bacterium proteamaculans* Elliott, Manual of bacterial plant pathogens, 1930, 186.)

Short yellow rods: 0.6 to 0.8 by 0.8 to 1.6 microns. Motile with one to three polar flagella. Without capsules. Gram-positive.

Gelatin colonies.

Gelatin slant: Liquefied.

Agar colonies.

Agar streak: Dirty white to yellow, surface raised, wet and shining, edges entire.

Broth: Well clouded after 24 hours, slight ring, no pellicle.

Litmus milk: Soft acid curd.

Potato.

Indol.

Nitrates.

Starch slightly hydrolyzed.

Acid and small amount of gas in dextrose and sucrose.

Anaerobic, facultative.

Optimum temperature 20° to 30°C.

Habitat: Causes a leaf spot of *Protea cynaroides*.

7. **Phytomonas juglandis** (Pierce) Bergey et al. (*Pseudomonas juglandis* Pierce, Bot. Gaz., *31*, 1901, 272; *Bacterium juglandis* Erw. Smith, Bacteria in relation to plant diseases, *1*, 1905, 171; Bergey et al., Manual, 3rd ed., 1930, 247.)

Short yellow rods: 0.5 by 1 to 2 microns, occurring singly or in pairs, sometimes in short chains. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Circular, entire, clear, becoming yellow.

Gelatin stab: Liquefied.

Agar colonies: Circular, entire, clear, becoming bright yellow.

Agar slant: Light yellow streak.

Broth.

Litmus milk.

Potato: Good chrome yellow growth.

Indol.

Nitrates.

Starch hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 30°C.

Habitat: Pathogenic to nuts, leaves and tender branches of the English walnut (*Juglans regia*).

8. **Phytomonas vascularum** (Cobb) Bergey et al. (*Bacillus vascularum* Cobb, Agr. Gazette of New South Wales, *4*, 1893, 777; *Bacterium vascularum*

Migula, System der Bakterien 1900, 512; *Pseudomonas vascularum* Erw. Smith, U. S. Dept. Agr., Div. Veg. Phys. and Path. Bul. 28, 1901, 153; Bergey et al., Manual, 1st ed., 1923, 179.)

Pale yellow rods: 0.4 by 1.0 micron, occurring singly, in pairs and in chains. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Small, circular, yellow, raised, viscid.

Gelatin stab: Yellow, moist, raised. No liquefaction.

Agar colonies: Pale yellow, moist, flat, glistening, entire.

Agar slant: Thin, scant, pale yellow, moist, glistening.

Broth: Turbid, with yellow sediment.

Litmus milk: Alkaline. Pale yellow sediment.

Potato: Yellow, smooth, moist, glistening.

Indol not formed.

Nitrates not reduced.

No acid or gas in carbohydrate media.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Causative agent in "Cobb's disease" of sugar cane.

9. **Phytomonas tritici** (Hutchinson) Bergey et al. (*Pseudomonas tritici* Hutchinson, Mem. India Dept. of Agric., Bact., Series 1, 1917, 169; Bergey et al., Manual, 3rd ed., 1930, 248; *Bacterium tritici* Elliott, Bacterial Plant Pathogens, 1930, 234.)

Yellow rods: 0.8 by 2.4 to 3.2 microns. Motile with a polar flagellum. Gram-negative.

Gelatin colonies.

Gelatin stab: Not liquefied.

Agar colonies: Bright yellow convex, edges entire, shining, moist, opaque at center.

Agar slant: Yellow, moist, raised, shining, precipitate in water of condensation. Agar turns brown.

Broth: Cloudy, yellow precipitate, thin ring.

Litmus milk: Litmus not blued, but reduced.

Potato: Slight yellow growth.

Indol.

Nitrates reduced to nitrites and ammonia.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 30°C.

Habitat: Causes a disease of wheat in India.

10. **Phytomonas pruni** (Erw. Smith) Bergey et al. (*Pseudomonas pruni* Erw. Smith, Science, N. S., *17*, 1903, 456; *Bacterium pruni* Erw. Smith, Bacteria in Relation to Plant Diseases, *1*, 1905, 171; Bergey et al., Manual, 1st ed., 1923, 179.)

Small rods. Motile with one to several polar flagella. Gram-negative.

Gelatin stab. No liquefaction.

Agar colonies.
Agar slant.
Broth: Turbid.
Litmus milk: Casein slowly precipitated and peptonized.
Potato.
Indol not formed.
Nitrates not reduced.
No gas in carbohydrate media.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature.
Habitat: The cause of "black spot" and canker in plum, peach, etc.

11. **Phytomonas medicaginis** (Sackett) Bergey et al. (*Pseudomonas medicaginis* Sackett, Science, N. S. *31*, 1910, 553; also Bull. 158, Colorado Agr. Exp. Sta., 1910; Bergey et al., Manual, 1st ed., 1923, 179; *Bacterium medicaginis* Elliott, Bacterial Plant Pathogens, 1930, 162.)

Short rods, yellow: 0.5 to 0.8 by 1.2 to 2.4 microns, occurring singly, in pairs and in long chains. Motile with one to four polar flagella. Gram-negative.

Gelatin stab: No liquefaction.
Agar colonies.
Agar slant: Filiform, becoming echinulate, smooth, glistening, translucent, grayish-white.
Broth: Slightly turbid, with pellicle and slight sediment.
Litmus milk: Unchanged.
Potato.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Associated with "stem blight" in alfalfa.

12. **Phytomonas xanthochlora** (Schuster) Bergey et al. (*Bacterium xanthochlorum* Schuster, Arbeiten aus der Kaiserl. Biolog. Anstalt. f. Land. u. Forstw., *8*, 1912, 452; Bergey et al., Manual, 1st ed., 1923, 180; *Pseudomonas xanthochlora* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten *2*, 5 Auf., 1928, 213.)

Rods: 0.75 by 1.25 to 3.0 microns, occurring singly and in pairs. Motile with a polar flagellum; occasionally two or three flagella occur at one pole. Gram-negative.

Gelatin colonies: Very small, circular, with brownish center.
Gelatin stab: Infundibuliform liquefaction.
Agar colonies: Circular, raised, finely granular.
Agar slant: Dry, thin, yellowish-white to greenish-white, fluorescent, wrinkled.

Broth: Turbid, with white pellicle and copious, white sediment.
Litmus milk: Slowly coagulated.
Potato: Reddish-brown growth.
Indol is formed.
Nitrates reduced to nitrites.
No acid or gas in carbohydrate media.
Starch not hydrolyzed.
H_2S is formed.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: The causative agent of "potato rot" in Germany.

13. **Phytomonas gummisudans** (McCullough) Bergey et al. (*Bacterium gummisudans* McCullough, Phytopath., *14*, 1924, 63; also Jour. of Agr. Research, *27*, 1924, 229; Bergey et al., Manual 2nd ed., 1925, 201.)

Short rods, 0.6 to 0.8 by 1.0 to 2.8 microns, occurring singly and in pairs in the tissues of plants and in long chains in broth. Motile, possessing a polar flagellum. Capsules are formed on beef peptone agar and potato dextrose agar. Gram-negative.

Gelatin: Slowly liquefied.

Agar colonies: Circular, pale yellow, transparent, smooth with striated internal structure.

Broth: Turbid, with thick, yellow ring, and thin viscid pellicle.

Litmus milk: Slightly acid with soft coagulum; slowly reduced; completely digested. Heavy yellow, viscid sediment. Tyrosin crystals are formed.

Potato: Abundant, pale yellow growth.
Indol is not formed.
Nitrates are not reduced.
Slight amounts of acid are formed in dextrose and sucrose media.
Ammonia and H_2S are formed.
Blood serum becomes translucent and is partly liquefied.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: The cause of bacterial blight on gladioli.

14. **Phytomonas citri** (Hasse) Bergey et al. (*Pseudomonas citri* Hasse, Jour. of Agr. Research, *4*, 1915, 97; *Bacterium citri* Doidge, Union So. Africa, Dept. Agr. Sci. Bul. *8*, 1916, 20; Bergey et al., Manual, 1st ed., 1923, 181.)

Rods, white: 0.5 to 0.7 by 1.5 to 2.0 microns, occurring singly and in pairs. Motile with a polar flagellum. Gram-negative.

Gelatin stab: Liquefied.
Agar colonies: Circular, yellow, entire, slightly raised, smooth.
Agar slant: Filiform, undulate, slightly raised, glistening, dull yellow.
Broth: Turbid, with yellow ring.
Litmus milk: Coagulated, with reddish liquid.

Potato: Bright yellow, spreading, raised.
Indol is formed.
Nitrates not reduced.
Acid and gas in dextrose, lactose, levulose, galactose, maltose, sucrose, asparagin, amygdalin, and mannitol.
Starch is hydrolyzed. Cytase is also produced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: The cause of citrus "canker."

15. **Phytomonas pelargoni** (Brown) Bergey et al. (*Bacterium pelargoni* Brown, Jour. Agr. Research, *23*, 1923, 372; *Pseudomonas pelargoni* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 181; Bergey et al., Manual, 3rd ed., 1930, 250.)
Rods with rounded ends, 0.6 by 1.0 micron, occurring singly, in pairs and in chains. Motile with a polar flagellum. Gram-negative.
Gelatin stab: Slow crateriform liquefaction.
Agar colonies: Circular, smooth, cream-colored, entire.
Agar slant: Cream-colored, smooth, glistening, entire.
Broth: Turbid, with slight pellicle.
Litmus milk: Slow coagulation and slight peptonization. Litmus reduced.
Potato: Thin, Naples yellow streak.
Indol formed.
Nitrates not reduced.
H_2S formed.
Starch slowly hydrolyzed.
No acid in carbohydrate media.
Aerobic, facultative.
Optimum temperature 25° to 28°C.
Habitat: Bacterial leaf spot of geranium.

16. **Phytomonas papavericola** (Bryan and McWhorter) *comb. nov.* (*Bacterium papavericola* Bryan and McWhorter, Jour. Agric. Research, *40*, 1930, 1.)
Short rods: 0.6 to 0.7 by 1.0 to 1.7 microns, occurring singly and in pairs. Motile by a polar flagellum. Encapsulated. Gram-negative.
Gelatin stab: Slowly liquefied.
Agar colonies: Circular, bright-yellow, smooth, convex, entire.
Agar slant: Filiform, translucent, butyrous becoming viscid.
Broth: Turbid with thin pellicle.
Litmus milk: Acid and coagulated. Reduction. Peptonization. Tyrosine crystals formed.
Potato: Heavy, yellow, slimy.
Indol is not formed.
Nitrates are reduced.

Acid in dextrose, levulose, galactose, maltose, lactose, sucrose, glycerol and mannitol.

Starch is hydrolized.

Ammonia is formed.

H_2S is formed.

Blood serum is liquefied.

Aerobic.

Optimum temperature 25 to 30°C.

Habitat: Causes blight on all exposed parts of Shirley Poppy and on leaves and pads of Oriental Poppy.

17. **Phytomonas campestris** var. **armoraciae** (McCulloch) Bergey et al. (*Bacterium campestre* var. *armoraciae* McCulloch, Jour. Agr. Research, *38*, 1929, 269; Bergey et al., Manual, 3rd ed., 1930, 251.)

Rods: 0.3 to 0.5 by 0.7 to 2.0 microns, occurring singly, in pairs and in long chains in broth cultures. Motile with a polar flagellum. Encapsulated. Gram-negative.

Gelatin stab: Liquefied.

Agar colonies: White, changing to pale yellow, becoming deep yellow, amorphous, ringed, translucent, becoming transparent.

Agar slant: Smooth, later contoured surface, transparent, apricot color, sometimes slightly viscid.

Broth: Turbid with thin pellicle and yellow sediment.

Litmus milk: Litmus slowly reduced.

Potato: Pale yellow streak, smooth, glistening, becoming brownish.

Indol formed.

Nitrates not reduced.

Ammonia formed.

H_2S formed.

Starch hydrolyzed.

Acid formed in dextrose, levulose, galactose, maltose, sucrose, glycerol and mannitol.

Blood serum liquefied.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Leaf spot on horseradish.

18. **Phytomonas cucurbitae** (Bryan) Bergey et al. (*Bacterium cucurbitae* Bryan, Science, N. S., *63*, 1926, 165; Bergey et al., Manual, 3rd ed., 1930, 251.)

Rods. Motile, with polar flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: Slowly liquefied.

Agar colonies: 4 mm. in diameter, convex, wax yellow with internal concentric markings.

Agar slant.

Broth: A heavy bright yellow rim, and sometimes a pellicle.

Litmus milk: Peptonized and a soft curd formed. No reddening, or bluing of the litmus. Litmus reduced.

Potato: Growth is abundant, yellow, viscid.

Indol.

Nitrates not reduced.

Starch hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 30°C.

Habitat: Causes "leaf spot" on the leaves of Hubbard squash.

19. **Phytomonas translucens** (Jones et al.) Bergey et al. (*Bacterium translucens* Jones, Johnson and Reddy, Jour. Agr. Research, *11*, 1917, 625; *Pseudomonas translucens* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 22; Bergey et al., Manual, 3rd ed., 1930, 252.)

Rods with rounded ends, 0.5 to 0.8 by 1.0 to 2.5 microns, occurring singly and in pairs. Encapsulated. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Small, circular, smooth, glistening, wax yellow.

Gelatin stab: Stratiform liquefaction.

Agar colonies: Circular, smooth, glistening, amorphous, wax yellow, tinged with old-gold, soft.

Agar slant: Moderate, filiform, wax yellow, opaque, smooth, glistening, amorphous, raised.

Broth: Turbid, with pellicle and flocculent sediment.

Litmus milk: Slight acidity, yellow growth at top. Litmus reduced.

Potato: Abundant, spreading, smooth, glistening, wax-yellow, slimy.

Indol formed in small amount.

Nitrates not reduced.

Ammonia produced

Starch not hydrolyzed.

Acid formed in dextrose, lactose, maltose, sucrose, glycerol and mannitol.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Bacterial blight of barley.

20. **Phytomonas marginalis** (Brown) Bergey et al. (*Bacterium marginale* Brown, Journal of Agricultural Research, *13*, 1918, 386; *Pseudomonas marginalis* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 288; Bergey et al., Manual, 1st ed., 1923, 182.)

Rods: 0.4 to 0.8 by 1.25 to 2.0 microns, occurring singly or in short chains. Motile with one or two polar flagella. Gram-negative. Encapsulated.

Gelatin colonies: Small, auricular, cream-colored margin.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Circular, smooth, bluish-white to cream color. Medium becomes yellowish-green.

Agar slant: Thin, yellow, spreading.

Broth: Slightly turbid, with pellicle. The medium becomes apple green. Ochre-yellow sediment.

Litmus milk: Slightly acid, soft curd, heavy pellicle, becoming alkaline.

Potato: Thin, watery layer, becoming pinkish to tan color.

Indol is not formed.

Nitrates reduced to nitrites and ammonia.

Starch is slowly hydrolyzed.

Acid in dextrose and sucrose.

Aerobic, facultative.

Optimum temperature 25° to 26°C.

Habitat: Causes disease in lettuce. Encountered in Kansas.

21. **Phytomonas beticola** (Smith, Brown and Townsend) Bergey et al. (*Bacterium beticolum* Smith, Brown and Townsend, Bureau of Plant Industry, U. S. Dept. of Agr., Bul. 213, 1911, 194; Bergey et al., Manual, 1st ed., 1923, 182; *Pseudomonas beticola* Stapp, Sorauer's Handbuch Pflanzenkrankheiten, *2*, 5 Auf., 1928, 102.)

Rods with rounded ends: 0.6 to 0.8 by 1.5 to 2.0 microns, occurring singly, in pairs and in chains. Motile with several polar flagella. Encapsulated. Gram-negative.

Gelatin colonies: Small, yellowish, circular, smooth.

Gelatin stab: Slowly liquefied.

Agar colonies: Small, circular, yellowish, smooth or wrinkled.

Agar slant: Smooth, yellowish to buff, glistening.

Broth: Turbid, with yellow ring and sediment.

Litmus milk: Yellow ring and pellicle, becoming solidified, alkaline, reduced.

Potato: Shows moderate yellow growth.

Indol is formed.

Nitrates are reduced.

Blood serum not liquefied.

Acid formed in dextrose, levulose, galactose, maltose, lactose, sucrose, glycerol and mannitol.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Causes "tuberculosis" of beets.

22. **Phytomonas vesicatora** (Doidge) Bergey et al. (*Bacterium vesicatorum* Doidge, Jour. Dept. Agr., So. Africa, *1*, 1920, 718; Also Ann. Applied Biol., *7*, 1921, 407; *Bacterium exitiosum* Gardner and Kendrick, Jour. Agr. Res., *21*, 1921, 1st page 141; *Pseudomonas exitiosa* Gerdner and Kendrick, Phytopath., *11*, 1921, 55; *Phytomonas exitiosa* Bergey et al., Manual, 1st ed., 1923, 183; *Pseudomonas vesicatora* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 auf., 1928, 259; Bergey et al., Manual, 3rd ed., 1930, 253.)

Rods: 0.5 to 0.75 by 0.6 to 4.0 microns, occurring singly and in pairs, occasionally in short chains. Capsules are formed. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Circular, yellow.

Gelatin stab: Crateriform liquefaction, with yellow sediment in liquefied medium.

Agar colonies: Circular, convex or pulvinate, smooth, glistening, translucent, straw-yellow, entire.

Agar slant: Spreading, smooth, raised, yellow, entire

Broth: Turbid, with yellow pellicle and sediment.

Litmus milk: Litmus reduced. Slowly peptonized. Alkaline.

Potato: Abundant, yellow, spreading, raised.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, lactose, sucrose, dextrin and glycerol.

Potato and corn starch hydrolyzed.

Löffler's blood serum liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: The cause of bacterial "spot" of tomato, forming lesions on leaf, rachis, petiole, cotyledon, stem and green fruit. Also pathogenic on leaves and fruit of *Capsicum annum* L., and on leaves of *Solanum tuberosum* L.

23. **Phytomonas vitians** (Brown) Bergey et al. (*Bacterium vitians* Brown, Jour. of Agr. Research, *13*, 1918, 367; Bergey et al., Manual, 1st ed., 1923, 183; *Pseudomonas vitians* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 287.)

Rods: 0.4 to 0.8 by 0.6 to 1.2 microns, occurring singly, in pairs and occasionally in short chains. Motile with one to several polar flagella. Gram-negative.

Gelatin colonies: Very slow development. Yellow, circular, shiny.

Gelatin stab: Slow crateriform liquefaction.

Agar colonies: Thin, circular, cream-color, entire.

Agar slant: Thin, flat, yellow, spreading, opaque, smooth, viscid, entire.

Broth: Slightly turbid, with pellicle which sinks to the bottom.

Litmus milk: Slowly reduced, becoming alkaline, coagulated.

Potato: Empire-yellow, thick, smooth, viscid.

Indol: Slight amount formed.

Nitrates not reduced.

H_2S formed.

Starch is slightly hydrolyzed.

Aerobic, facultative.

Optimum temperature 26° to 28°C.

Habitat: Causes disease in lettuce. Encountered in South Carolina.

24. **Phytomonas mellea** (Johnson) Bergey et al. (*Bacterium melleum* Johnson, Jour. Agr. Research, *23*, 1927, 481; *Pseudomonas mellea* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 275; Bergey et al., Manual, 3rd ed., 1930, 254.)

Rods with rounded ends, 0.5 to 0.8 by 1.0 to 2.4 microns, occurring singly, in pairs, and occasionally in short chains. Motile with one to several polar flagella. Gram-negative.

Gelatin stab: Rapid, stratiform liquefaction.

Colonies on potato-dextrose agar: Circular, grayish-white, becoming yellow, with yellow tinge in the medium.

Potato-dextrose agar slant: Honey-yellow to deep orange, spreading, streak.

Broth: Turbid, with thin pellicle and flaky sediment.

Litmus milk: Alkaline, slow precipitation and peptonization, the liquefied portion assuming a tan color.

Potato: Brownish-yellow streak.

Indol not formed.

Nitrates not reduced.

Starch hydrolyzed.

Blood serum liquefied.

Aerobic, facultative.

Optimum temperature 25° to 28°C.

Habitat: Bacterial leaf spot of tobacco.

25. **Phytomonas holicicola** (Elliott) *comb. nov.* (*Bacterium holicicola* Elliott, Jour. Agr. Research, *40*, 1930, 972.)

Rods: 0.75 by 1.6 microns, with rounded ends, occurring singly and in pairs, occasionally in short chains. Motile, with one or two polar flagella. Gram-negative.

Gelatin stab: Slowly liquefied.

Agar colonies: Circular, ombonate, smooth, glistening, translucent, becoming opaque, wax-yellow, butyrous.

Broth: Moderate growth, irregular ring growth on surface.

Litmus milk: Cleared without coagulation.

Indol is not formed.

Nitrate reduction doubtful.

Ammonia is formed.

H_2S is formed.

Starch is hydrolized.

Slight acidity in sucrose.

Aerobic.

Optimum temperature 28°–30°C.

Habitat: The cause of bacterial leaf streaks in sorghum.

26. **Phytomonas amaranthi** (Erw. Smith) Bergey et al. (*Bacterium amaranthi* Erw. Smith, Bacteria in Relation to Plant Diseases, *3*, 1914,

148; Bergey et al., Manual, 1st ed., 1923, 186; *Pseudomonas amaranthi* Elliott, Bacterial Plant Pathogens, 1930, 316.)

Short rods with rounded ends, occurring singly. Motile with a polar flagellum. Gram-negative.

Gelatin stab: No liquefaction.

Agar slant: Dirty white to pale yellowish, becoming yellow.

Broth: Turbid.

Litmus milk: Alkaline.

Potato: Homogeneous, moist, glistening, thin, translucent, pale yellow, becoming ochre yellow.

Indol not formed.

Nitrates reduced to nitrites.

No gas in carbohydrate media.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Found in disease of amaranths.

27. **Phytomonas solanacearum** (Erw. Smith) Bergey et al. (*Bacillus solanacearum* Erw. Smith, U. S. Dept. Agr. Div. Veg. Phys. and Path. Bul. 12, 1896; *Bacterium solanacearum* Erw. Smith, Bacteria in Relation to Plant Diseases, *3*, 1914, 178; *Pseudomonas solanacearum* Erw. Smith, *ibid*; Bergey et al., Manual, 1st ed., 1923, 186.)

Note: Elliott, Bacterial Plant Pathogens, 1930, 203, lists the following synonyms: *Bacillus nicotianae* Nyeda, Cent. f. Bakt., 13, 1904, 327; *Bacillus sesami* Molkoff, Cent. f. Bakt., *16*, 1906, 664; *Pseudomonas sesami* Molkoff, *ibid.*; *Bacillus musae* Rorer, Phytopath., *1*, 1911, 45; *Bacillus musarum* Zeman, Rev. Facul. Agr. Univ. La Plata, *14*, 1921, 17; *Erwinia nicotianae* Bergey et al., Manual, 1st ed., 1923, 186.

Rods: 0.5 by 1.5 microns, occurring singly and in pairs, with rounded ends. The rods are white. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Small, thin, smooth, white, glistening.

Gelatin stab: No liquefaction, white circular, glistening, surface growth.

Agar colonies: White, grayish, becoming brownish, circular, moist, glistening.

Agar slant: Smooth, moist, white, glistening, becoming brownish.

Broth: Turbid, with white sediment.

Litmus milk: Alkaline.

Potato: Gray-white, becoming brown to black.

Indol not formed.

Nitrates reduced to nitrites.

No gas in carbohydrate media.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 35° to 37°C.

Habitat: The cause of "brown rot" in *Solanaceae*.

28. **Phytomonas woodsii** (Smith) Bergey et al. (*Bacterium woodsii* Smith, Bacteria in Relation to Plant Diseases, Carnegie Institution, Washington, *2*, 1911, 62; *Pseudomonas woodsii* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 231; Bergey et al., Manual, 3rd ed., 1930, 256.)

Rods, occurring singly and in pairs. Motile.

Gelatin stab: No liquefaction.

Agar colonies: Small, white, circular.

Agar slant: White.

Broth: Turbid.

Litmus milk: Becoming alkaline.

Potato: White.

Indol.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Found in bacterial "spot" of carnations.

29. **Phytomonas glycinea** (Coerper) Bergey et al. (*Bacterium glycineum* Coerper, Jour. Agr. Research, *18*, 1919–1920, 188; Bergey et al., Manual, 3rd ed., 1930, 256.)

Note: Elliott, Bacterial Plant Pathogens, 1930, 134, considers *Phytomonas sojae* a synonym of *Phytomonas glycinea*.

Rods, with rounded ends, 1.2 to 1.5 by 2.3 to 3.0 microns, occurring singly and in pairs, encapsulated. Motile with several polar flagella. Gram-negative.

Gelatin colonies: Small, circular, the medium turning chestnut brown.

Gelatin stab: No liquefaction.

Agar colonies: Circular, glistening, convex, entire, creamy-white, tinged with brown.

Potato agar slant: Moderate, flat, slimy, cream-colored, tinged with brown, margin repand.

Broth: Turbid, dark brown at top.

Litmus milk: Alkaline.

Potato: Spreading, flat, smooth, yellowish-white.

Indol formed.

Nitrates not reduced.

Starch not hydrolyzed.

Acid in dextrose and sucrose.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Bacterial leaf spot of soy-bean.

30. **Phytomonas erodii** (Lewis) Bergey et al. (*Bacterium erodii* Lewis, Phytopath., *4*, 1914, 231; *Pseudomonas erodii* Lewis, *ibid.*; Bergey et al., Manual, 3rd ed., 1930, 256.)

Rods, short with rounded ends, 0.6 to 0.8 by 1.2 to 1.8 microns. Motile with one to three polar flagella. Gram-negative.

Gelatin stab: Slow liquefaction.

Agar colonies: circular, whitish, translucent, moist and glistening.

Agar slant: Translucent, moist, cream-colored, smooth. Agar changed to yellowish green.

Broth: Turbid, turning green. Thin pellicle.

Litmus milk: No clot, slow peptonization. Old cultures green.

Potato: Streak yellow, changing to cream, and later brown, and finally to fluorescent green.

Slight indol formation.

Nitrates not reduced.

Carbohydrates: Slight acidity from glycerol, glucose, sucrose, and lactose.

Aerobic facultative.

Optimum temperature: 27°C.

Habitat: Bacterial leaf spot of geranium.

31. **Phytomonas syringae** (Van Hall) Bergey et al. (*Pseudomonas syringae* Van Hall, Kennis der Bakter. Pflanzenziekte, Inaug. Dissert., Amsterdam, 1902; *Bacterium syringae* Edw. Smith, Bacteria in Relation to Plant Diseases, *1*, 1905, 63; Bergey et al., Manual, 3rd ed., 1930, 257.)

Note: Elliott, Bacterial Plant Pathogens, 1930, 217, lists the following synonyms; *Bacterium citriputeale* C. O. Smith, Phytopath., *3*, 1913, 69; *Bacterium citrarefaciens* Lee, Jour. Agr. Res., *9*, 1917, 1; *Pseudomonas citrarefaciens* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 190; *Pseudomonas citriputealis* Stapp, *ibid.*; *Phytomonas citriputealis* Bergey et al., Manual, 3rd ed., 1930, 278.)

Rods: 0.6 by 1.8 microns, ranging from 0.3 to 0.9 by 1.2 to 3.0 microns, with rounded ends, occurring singly and in pairs. Motile with one to four polar flagella. Rods white. Gram-negative.

Gelatin colonies: Circular.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Circular, white, smooth, glistening, convex, finely granular, entire, becoming lacerate, greenish and fluorescent.

Agar slant: Filiform to echinulate, convex, smooth, glistening, translucent, slimy, medium uniformly fluorescent green.

Broth: Thin pellicle with slightly viscid sediment.

Litmus milk: Coagulated; peptonized. Litmus reduced; alkaline.

Potato: Moderate, filiform to echinulate, spreading, convex to flat, glistening, cream-buff color.

Indol is formed.

Nitrates not reduced. Ammonia formed.

No acid formed in carbohydrate media.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 22°C.

Habitat: "Black pit" and "wither pit" of lemon trees and "blight" of lilac.

32. **Phytomonas citriputealis** (C. O. Smith) Bergey et al. (*Bacterium citriputeale* C. O. Smith, Phytopathology, *3*, 1913, 280; *Pseudomonas citriputealis* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Aufl., 1928, 190; Bergey et al., Manual, 3rd ed., 1930, 278.)

Note: Elliott, Bacterial Plant Pathogens, 1930, 217, considers *Phytomonas citriputealis* a synonym of *Phytomonas syringae*.

Rods, with rounded ends, 0.5 to 1.0 by 2.0 to 4.0 microns, occurring singly and in pairs. Motile with a single polar flagellum.

Gelatin stab: Stratiform liquefaction.

Agar colonies: Circular, entire, granular, grayish-white.

Agar slant: Gray, thin, spreading.

Broth.

Litmus milk: Alkaline.

Potato: Gray, elevated.

Indol is not formed.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Causes "black pit" of lemons.

33. **Phytomonas trifoliorum** (Jones et al.) Burkholder. (*Bacterium trifoliorum* Jones, Williamson, Wolf, and McCulloch, Jour. Agr. Res., *25*, 1923, 471; Burkholder, Phytopath., *16*, 1926, 922; *Pseudomonas trifoliorum* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 177.)

Rods with rounded ends, 0.4 to 1.0 by 1.2 to 3.0 microns, occurring singly, at times in short chains. Encapsulated. Motile with one to four polar flagella. Gram-negative.

Gelatin colonies: Circular, white, smooth, finely granular, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular, white, convex, smooth, glistening, entire.

Agar slant: Spreading, white, glistening with entire margin.

Broth: Turbid, fluorescent.

Litmus milk: Coagulation, alkaline, peptonized.

Potato: Faintly yellowish-white, smooth streak.

Indol.

Nitrates are not reduced.

Starch not hydrolyzed.

Acid in dextrose and sucrose.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Bacterial leaf spot of clovers.

34. **Phytomonas atrofaciens** (McCullough) Bergey et al. (*Bacterium atrofaciens* McCullough, Jour. of Agr. Research, *18*, 1920, 549; Bergey et al., Manual, 1st ed., 1923, 185; *Pseudomonas atrofaciens* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 17.)

Rods: 0.6 by 1.0 to 2.7 microns, with rounded ends, occurring singly and in chains. Motile with one to four polar flagella. Encapsulated. Gram-negative.

Gelatin colonies: Liquefy quickly.

Gelatin stab: Slow crateriform liquefaction.

Agar colonies: White, becoming greenish-white, with fish scale marking along edge.

Agar slant: Thin, white, transparent, the medium becoming green.

Broth: Turbid, with delicate pellicle. The medium becoming yellowish-green.

Litmus milk: Alkaline, slowly peptonized.

Potato: Yellowish-white, becoming greenish-brown.

Indol is formed.

Nitrates not reduced.

Starch not hydrolyzed.

H_2S formed.

Aerobic, facultative.

Optimum temperature 25° to 28°C.

Habitat: Causes "glumerot" of wheat—(*Triticum vulgare* L.).

35. **Phytomonas holci** (Kendrick) Bergey et al. (*Bacterium holci* Kendrick, Phytopath, *16*, 1926, 237; *Pseudomonas holci* Kendrick, *ibid.*; Bergey et al., Manual, 3rd ed., 1930, 258.)

Rods: 0.7 by 2.0 microns, occurring singly and in pairs. Motile with one to four polar flagella. Gram-negative.

Gelatin stab: Quickly liquefied.

Agar colonies: Circular, raised, smooth, entire, grayish-white, slightly fluorescent by transmitted light.

Agar slant: Fluorescent.

Broth: Turbid. Fluorescent.

Litmus milk: Peptonized.

Potato.

Indol not formed.

Nitrates reduced to nitrites.

Starch not hydrolyzed.

Acid in dextrose and sucrose.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Halo bacterial spot on *Holcus sorghum* and on *Zea mays*.

36. **Phytomonas tolaasi** (Paine) Bergey et al. (*Pseudomonas tolaasi* Paine, Ann. Appl. Biol., *5*, 1919, 210; Bergey et al., Manual, 3rd ed., 1930, 259; *Bacterium tolaasi* Elliott, Bacterial. Plant Pathogens, 1930, 226.)

Rods: 0.4 to 0.5 by 0.9 to 1.7 microns. Motile with one to several polar flagella. Gram-negative.

Gelatin colonies: 5 to 6 mm. in diameter.

Gelatin stab: Liquefied.

Agar colonies: Round, raised, wet-shining; later spreading; greenish fluorescent pigment.

Agar slant: Dirty bluish-white streak, 2 mm. in width, raised, flat contour.

Broth: Well clouded, thick pellicle.
Litmus milk: Coagulation, alkaline, peptonized.
Potato: White, wet, shining raised mass becoming slightly yellow medium discolored.
Indol slight.
Nitrates not reduced.
Starch: Feeble if any.
Acid but no gas in dextrose. No acid in lactose or sucrose.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Causes a brown blotch of cultivated mushrooms.

37. **Phytomonas bowlesii** Lewis and Watson. (Phytopath, *17*, 1927, 507; *Bacterium bowlesii* Elliott, Bacterial Plant Pathogens, 1930, 96.)
Straight rods, occurring singly, sometimes in pairs or short chains. Motile with flagella at each pole. Gram-negative.
Gelatin colonies.
Gelatin stab: Rapid liquefaction.
Agar colonies: 5 to 7 mm. in diameter, smooth, glistening, somewhat yellowish. Margins entire. Green fluorescent pigment formed.
Agar slant: Yellowish, moist, glistening and viscid. Green fluorescent pigment formed.
Broth: Uniformly cloudy, a heavy viscid sediment.
Litmus milk: Coagulation of milk, digestion of protein, slow. Alkaline reaction. Litmus not reduced.
Potato: Yellowish slime covers the surface.
Indol produced.
Nitrates are reduced to nitrites.
Starch not hydrolyzed.
Acid but no gas formed in dextrose.
Aerobic, facultative.
Optimum temperature 27°C.
Habitat: Pathogenic to *Bowlesia septentrionalis*.

38. **Phytomonas viridilivida** (Brown) Bergey et al. (*Bacterium viridilividum* Brown, Jour. of Agr. Research, *4*, 1915, 475; Bergey et al., Manual, 1st ed., 1923, 187; *Pseudomonas viridilividum* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 287.)
Rods: 0.4 to 0.5 by 0.7 to 3.0 microns, occurring singly with rounded ends. Without capsule. Motile with one to three polar flagella. Rods are white in the plant. Gram-negative.
Gelatin stab: Slow liquefaction.
Agar colonies: Circular, cream-white, smooth, translucent, entire.
Agar slant: Shows matted appearance, or yellowish bands with lighter margin.
Broth: Turbid, with green color.
Litmus milk: Alkaline, becoming clear.

Potato: Dark, blue-green at first, the color disappearing after a week.
Indol is formed.
Nitrates not reduced.
No acid in carbohydrate media.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 20° to 23°C.
Habitat: Isolated from diseased lettuce leaves.

39. **Phytomonas vignae** (Gardner and Kendrick) Bergey et al. (*Bacterium vignae* Gardner and Kendrick, Science, N. S., *57*, 1923, 275; *Bacterium viridifaciens* Tisdale and Williamson, Jour. Agr. Research, *25*, 1923, 141; *Pseudomonas viridifaciens* Tisdale and Williamson, 1923, *ibid.*; Bergey et al., Manual, 1st ed., 1923, 188; *Phytomonas viridifaciens* Bergey et al., Manual, 2nd ed., 1925, 208.)

Rods: 0.5 by 1.5 to 2.0 microns, with rounded ends, occurring singly and in pairs. Motile, possessing one to five polar flagella. Gram-negative.

Gelatin stab: Rapid liquefaction.

Agar colonies: Circular, grayish-white, smooth, shiny, pulvinate or umbonate, with slight greenish fluorescence by transmitted light.

Agar slant: Grayish-white, smooth, layer with slightly greenish fluorescence.

Broth: Turbid.
Litmus milk: Peptonized; becoming alkaline.
Potato: Grayish-white layer.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed
Slow liquefaction of blood serum.
Acid in dextrose and sucrose.
Aerobic, facultative.
Optimum temperature 25°C.

Habitat: Produces "leaf spot" on cow pea, *Vigna sinensis* (L.) Endl., and on lima beans, *Phaseolus limitus* L.

40. **Phytomonas delphinii** (Smith) Bergey et al. (*Bacillus delphinii* Smith, Science, N. S., *19*, 1904, 417; *Bacterium delphinii* Bryan, Jour. Agr. Research, *28*, 1924, 261; *Pseudomonas delphinii* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, 1928, 106; Bergey et al., Manual, 3rd ed., 1930, 261.)

Rods: 0.6 to 0.8 by 1.5 to 2.0 microns, with rounded ends occurring singly and in pairs. Cultures in Fermi's solution show capsules. Motile with one to six bipolar flagella. Gram-negative.

Gelatin colonies: Small, circular, white, liquefying.

Gelatin stab: Liquefaction napiform, becoming stratiform. Deep green fluorescence.

Agar colonies: Circular, slightly convex, white, smooth, transparent, finely granular.

Agar slant: Thin, white, smooth, glistening, transparent with wavy internal markings, and green fluorescence.
Broth: Turbid with delicate pellicle, and blue-green fluorescence
Litmus milk: Alkaline, litmus reduced, copious white sediment.
Potato: Moderate, thin, spreading, tan-colored streak.
Indol not produced.
Nitrates not reduced.
Starch is hydrolyzed.
Acid in dextrose, levulose, galactose, and arabinose.
Ammonia is produced.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Cause of "black spot" in delphinum.

41. **Phytomonas pseudozoogloeae** (Honing) Bergey et al. (*Bacterium pseudozoogloeae* Honing, Bul. Deli Proefstat. Medan, No. 1, p. 10, 1914; Bergey et al., Manual, 3rd ed., 1930, 261.) (Description from Jour. of Agric. Res., *23*, 1923, 490).
Short rods: 0.7 to 1 by 1.5 microns. Motile with one to two polar flagella. Gram-negative.
Gelatin colonies.
Gelatin stab: Liquefied. Yellowish green fluorescence.
Agar colonies.
Agar slant.
Broth.
Litmus milk: Rendered acid.
Potato.
Indol.
Nitrates not reduced.
Starch not hydrolyzed.
Acid in dextrose, lactose and sucrose.
Aerobic, facultative.
Optimum temperature 20° to 30°C.
Habitat: Produces a black rust of tobacco.

42. **Phytomonas cerasi** (Griffin) Bergey et al. (*Pseudomonas cerasi* Griffin, Science, N. S., *34*, 1911, 615; Bergey et al., Manual, 3rd ed., 1930, 262; *Bacterium cerasi* Elliott, Bacterial Plant Pathogens, 1928, 109.)
Rods: 0.5 to 0.8 by 1.5 to 2.5 microns, occurring singly or in pairs. Motile with one to two polar flagella. Gram-negative.
Gelatin colonies.
Gelatin stab: Infundibuliform liquefaction.
Agar colonies: Green fluorescence.
Agar slant: Moderate, echinulate, flat, glistening, smooth, opaque, butyrous, decided odor, medium green.
Broth: Turbid. Odor.
Litmus milk: Alkaline, coagulated, peptonized. Litmus reduced.

Potato: Moderate, flat, smooth.
Indol.
Nitrates not reduced.
Ammonia not produced.
Starch not hydrolyzed.
Acid but no gas in dextrose and sucrose. No acid in lactose.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Causes bacterial gummosis of cherries.

43. **Phytomonas martyniae** (Elliott) Bergey et al. (*Bacterium martyniae* Elliott, Jour. Agr. Research, *29*, 1924, 483; *Pseudomonas martyniae* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 278; Bergey et al., Manual, 3rd ed., 1930, 262.)

Rods: 0.5 to 0.7 by 1.3 to 2.2 microns, occurring singly and in pairs. Motile with one or several bipolar flagella. Gram-negative.

Gelatin colonies: Gray, circular, with filamentous margin. Liquefied. Slightly fluorescent.

Gelatin stab: Stratiform liquefaction, becoming slightly fluorescent.

Agar colonies: Gray, circular, smooth, raised, glistening, with fish-scale markings, margin entire, becoming greenish.

Agar slant: Moderate, white filiform, raised, butyrous, opalescent, medium turning greenish-brown.

Broth: Slight turbidity with slight sediment. Fluorescent.
Litmus milk: Slightly acid, peptonized. Litmus reduced.
Potato: Growth cream to tan color.
Indol not formed.
Nitrates reduced to nitrites.
Acid formed in dextrose, galactose, sucrose and arabinose.
Starch slowly hydrolyzed.
Blood serum shows slight liquefaction.
Aerobic, facultative.
Optimum temperature.
Habitat: Cause of "black spot" on *Martynia louisiana*.

44. **Phytomonas nectarophila** (Doidge) Bergey et al. (*Bacterium nectarophila* Doidge, Ann. Appl. Biol., *4*, 1917, 73; Bergey et al., Manual, 3rd ed., 1930, 262.)

Short rods: 0.5 to 0.7 by 0.6 to 1 micron, occurring singly or in pairs. Capsules present. Motile with one to five polar flagella. Gram-negative.

Gelatin colonies: About 4 mm. in three days. Thin, spreading, irregular margin, dull except at center.

Gelatin stab: Not liquefied.

Agar colonies: Spreading, subcircular to irregular, edges auriculate-lacerate; coppery by transmitted light, creamy white to dull green-yellow by reflected. Green fluorescent.

Agar slant: Wet, shiny, yellowish-white, flat, smooth, edges undulate.

Broth: Heavy clouding to turbid pellicle formed. Green fluorescent pigment.

Litmus milk: Slowly peptonized; litmus reduced.

Potato: Creamy white, wet-shining streak.

Indol not formed.

Nitrates not reduced.

Starch slowly hydrolyzed.

Acid in dextrose. No acid in sucrose and lactose.

Anaerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Causes a blight of pear blossoms.

45. **Phytomonas marginata** (McCullough) Bergey et al. (*Bacterium marginatum* McCullough, Science, N. S., *54*, 1921, 115; Bergey et al., Manual, 1st ed., 1923, 188.)

Rods: Varying considerably in length, 0.5 to 0.8 by 1.0 to 3.5 microns, frequently in pairs and forming chains in broth. Motile with one or two polar flagella. Gram-negative.

Agar colonies: Circular, smooth, slightly raised center, surrounded by a wide, thin border, more or less irregular margin. Growth white, extremely viscid.

Gelatin stab: Liquefied.

Agar slant: White, smooth, viscid.

Broth: Turbid.

Litmus milk: Slightly acid; peptonized.

Potato: Grayish-white streak.

Indol is formed.

Nitrates reduced to nitrites and ammonia.

Acid in various carbohydrate media.

Starch not hydrolyzed.

Löffler's blood serum is liquefied.

Aerobic, facultative.

Optimum temperature 28° to 30°C.

Habitat: Pathogenic in leaves of gladiolus, forming circular to elliptical, rusty-red to dull brown or purplish spots.

46. **Phytomonas avenae** (Russell) Bergey et al. (*Bacillus avenae* Russell, The Johns Hopkins Hospital Reports, *3*, 1894, 260; The two following names were proposed independently for an organism that is believed to be the same as the above, *Pseudomonas avenae* Manns, and *Bacillus avenae* Manns, Ohio Agr. Exp. Station, Bull. 210, 1909, 133; Bergey et al., Manual, 3rd ed., 1930, 263.)

White short rods: 0.5 to 1 by 1 to 2 microns. Motile with one to three polar flagella. Gram-negative.

Gelatin colonies: White, circular, margins entire, slow growing.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Slow growing, circular, smooth, edges entire, amorphous.

Agar slant: Scant to moderate filiform, flat, glistening, opaque to opalescent, non-chromogenic, slimy consistency.

Broth: Clouds slowly, sediment scant, yellow.

Litmus milk: Very slightly acid.

Potato: Moderate, dull, non-chromogenic, viscid.

Indol not formed.

Nitrates reduced to nitrites.

Ammonia produced.

Starch not hydrolyzed.

Acid but no gas in dextrose and sucrose. No acid in lactose.

Anaerobic, facultative.

Optimum temperature 20° to 30°C.

Habitat: Pathogenic in blades of oats, corn, timothy, wheat, barley, blue grass.

Note: This description is adapted from Manns, Ohio Agr. Exp. Station, Bul. 210, 1909. Elliott, Bacterial Plant Pathogens, 1930, 122 considers *Phytomonas avenae* a synonym of *Phytomonas coronafaciens*.

47. **Phytomonas hibisci** (Nakata and Takimoto) Bergey et al. (*Bacterium hibisci*, Nakata and Takimoto, Ann. of Phytopath. Soc. of Japan, *1*, 1923, 13; *Pseudomonas hibisci* Stapp, Soraurer's Handbuch der Pflanzenkrankheiten, 5 Aufl., *2*, 1928, 203; Bergey et al., Manual, 3rd ed., 1930, 264.)

Rods: 0.6 to 0.7 by 1.2 to 2 microns, occurring singly or in pairs, sometimes in chains. Motile with one to two polar flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: Slowly liquefied.

Agar colonies: Smooth, circular with margins entire, wet, shiny cement-like colonized by reflected light, fine granular in center.

Agar slant.

Broth: Cloudy, ring production and heavy sediment.

Litmus milk: Slowly peptonized.

Potato.

Indol not produced.

Nitrates slightly reduced.

Starch fully hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 30°C.

Habitat: Causes a leaf spot of *Hibiscus* in Korea.

48. **Phytomonas destructans** (Potter) Bergey et al. (*Pseudomonas destructans* Potter, Proc. Univ. of Durham Philos. Soc., 1899, 165; *Bacterium destructans* Nakata, Nakajiina and Takimoto, Tech. Rept. Korea Ind. Farm, 1922; Bergey et al., Manual, 3rd ed., 1930, 264.)

Rods: 0.75 to 0.9 by 1.3 to 3 microns. Motile with a polar flagellum. Gram-positive.

Gelatin colonies: Large, round, whitish-gray, margin fibrillated

Gelatin stab: Liquefied.

Agar colonies: Round or slightly lobed, opalescent, sometimes spreading.
Agar slant.
Broth: Turbid, no pellicle, heavy sediment.
Litmus milk.
Potato.
Indol.
Nitrates reduced.
Starch hydrolyzed.
Acid in dextrose, sucrose and lactose.
Anaerobic, facultative.
Optimum temperature 20° to 30°C.
Habitat: Produces a rot of turnips.

49. **Phytomonas barkeri** (Berridge) Bergey et al. (Bacillus of pear blossom disease, Ann. Appl. Biol., *1*, 1914, 94; Barker and Grove's organism, Doidge, Ann. Appl. Biol., *4*, 1917, 50; *Bacillus barkeri* Berridge, Ann. Appl. Biol., *4*, 1924, 73; Bergey et al., 3rd ed., 1930, 265; *Bacterium barkeri* Elliott, Bacterial Plant Pathogens, 1930, 95.)

Rods, occurring singly or in pairs, 0.5 to 0.8 by 2 to 4 microns. Motile with several polar flagella. Gram-positive.

Gelatin colonies: 6 to 8 mm. in diameter, concave, moist, and glistening, semi-transparent with a white nucleus in center. Surrounded by concentric rings.

Gelatin stab: Liquefied.

Agar colonies: Round to irregular, glistening, translucent 0.5 to 3 mm. Flat whitish, spreading.

Agar streak.
Broth: Good clouding with a thin pellicle.
Milk: Slow peptonization.
Potato: A yellowish-white broad, smooth-edged growth.
Indol not formed.
Nitrates.
Starch: Feeble action.
No acid in dextrose, sucrose and lactose.
Aerobic, facultative.
Optimum temperature 20° to 30°C.
Habitat: Causes a disease of fruit blossoms.

50. **Phytomonas coronafaciens** (Elliott) Bergey et al. (*Bacterium coronafaciens* Elliott, Jour. of Agr. Research, *19*, 1920, 139; Bergey et al., Manual, 1st ed., 1923, 180.)

Note: Elliott, Bacterial Plant Pathogens, 1930, 122 considers *Phytomonas avenae* a synonym of *Phytomonas coronafaciens.*

Rods, white: 0.65 by 2.3 microns, occurring singly, in pairs and long chains. Forms pseudozooglea. Encapsulated. Motile with polar flagella. Gram-negative.

Gelatin colonies: Small, white, circular, entire.

Gelatin stab: Slight growth in stab. Crateriform liquefaction.

Agar colonies: White, circular, smooth, glistening, undulate.

Agar slant: Moderate, flat, white, glistening, translucent, slightly contoured, butyrous, undulate.

Broth: Turbid, with white, flocculent pellicle, which settles to the bottom.

Litmus milk: Soft coagulation. Litmus reduced. Slow peptonization. Alkaline.

Potato: Abundant, flat, smooth, glistening, butyrous to slimy, cream-colored. Medium turns dark gray.

Indol not formed.

Nitrates not reduced.

Acid in dextrose, galactose and sucrose.

Shows slight softening of potato; starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: Associated with "blade-blight" of oats.

51. **Phytomonas pisi** (Sackett) Bergey et al. (*Pseudomonas pisi* Sackett. Colorado Agr. Exp. Sta., Bull. 218, 1916, 19; *Bacterium pisi* Erw. Smith, An Introduction to Bacterial Diseases of Plants, 1920, 474; Bergey et al., Manual, 1st ed., 1923, 181.)

Short, white rods, 0.5 to 0.8 by 1.0 to 3.0 microns, with rounded ends, occurring singly and in pairs, and occasionally in long chains. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Circular.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Circular, slightly convex, grayish, undulate margin.

Agar slant: Filiform, grayish-white, flat, glistening, smooth, translucent.

Broth: Turbid, with pellicle and slight sediment.

Litmus milk: Coagulation. Litmus reduced. Alkaline reaction.

Potato: Filiform, slightly raised, smooth, cream to orange-yellow to yellowish-brown, in old culture.

Indol not formed.

Nitrates not reduced.

Acid in dextrose, galactose and sucrose.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 28°C.

Habitat: Causes "stem blight" in field and green peas. Pathogenic for alfalfa, sweet clover, crimson clover, mammoth clover and cow peas.

52. **Phytomonas matthiolae** (Brisi and Pavarino) Bergey et al. (*Bacterium matthiolae* Brisi and Pavarino, Atti della Reale Accad. dei Lincei Rend., *21*, 1912, 216; Bergey et al., Manual, 3rd ed., 1923, 266.) (Description from E. F. Smith's Bacteria in relation to plant diseases, *3*, 1914, 277.)

Rods: 0.4 to 0.6 by 2 to 4 microns. Motile. Gram-negative.

Gelatin colonies.

Gelatin stab: Liquefied.

Agar colonies: Circular, smooth, slightly raised, whitish, margin entire.

Agar slant: Wet, shining, raised, lobed margins, whitish, spreading over surface of medium.

Broth: Slightly cloudy. Greenish pigment.

Litmus milk: Coagulation and acid reaction.

Potato: A grayish white growth, wet, becoming pale yellow with age.

Indol.

Nitrates not reduced.

Starch hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 30°C.

Habitat: Causes a disease in stocks in Italy.

53. **Phytomonas angulata** (Fromme and Murray) Bergey et al. (*Bacterium angulatum* Fromme and Murray, Jour. Agr. Research, *16*, 1919, 219; *Pseudomonas angulata* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 271; Bergey et al., Manual, 3rd ed., 1930, 267.)

Rods with rounded ends, 0.5 by 2.5 microns, occurring singly and in pairs. Motile with lophotrichous flagella. Gram-negative.

Gelatin colonies: Small, circular, convex, smooth, glistening, white.

Gelatin stab: Liquefaction infundibuliform.

Agar colonies: Small, circular, smooth, glistening, opalescent, becoming dull white, entire.

Agar slant: Filiform, slightly raised, smooth, glistening, slimy.

Broth: Turbid with grayish-white sediment.

Litmus milk: Becoming alkaline.

Potato: Filiform, smooth, glistening, becoming dull yellow.

Indol formed.

Nitrates not reduced.

Acid in dextrose and sucrose media.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20° to 22°C.

Habitat: Angular leaf spot of tobacco plants.

54. **Phytomonas papulans** (Rose) Bergey et al. (*Pseudomonas papulans* Rose, Phytopath., *7*, 1917, 198; Bergey et al., Manual, 3rd ed., 1930, 267; *Bacterium papulans* Elliott, Bacterial Plant Pathogens, 1930, 175.)

Rods: 0.6 by 0.9 to 2.3 microns, occurring singly or in pairs. Motile with one to six polar flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: Slowly liquefied.

Agar colonies: Thin, smooth, circular, glistening, whitish.

Agar slant: Filiform, slightly convex, whitish growth.

Broth: Clouding and pellicle.

Litmus milk: Alkaline with a soft coagulum.
Potato: Whitish filiform to spreading growth, becoming brownish.
Indol not produced.
Nitrates not reduced.
Ammonia produced.
Starch not hydrolyzed.
Acid in dextrose and sucrose. No acid in lactose.
Aerobic, facultative.
Optimum temperature 25° to 28°C.
Habitat: Causes blister spot of apple.

55. **Phytomonas puerariae** (Hedges) Bergey et al. (*Bacterium puerariae* Hedges, Jour. of Agr. Res., *36*, 1928, 419; Bergey et al., Manual, 3rd ed., 1930, 267.)

Rods with rounded ends, 0.3 to 0.5 by 0.85 to 1.65 microns, occurring singly, in pairs and in chains. Motile with one to three polar flagella. Gram-negative.

Gelatin colonies.
Gelatin stab: Slow, saccate liquefaction.
Agar colonies: Circular, bluish-white, becoming opalescent, smooth, shining, translucent.
Agar slant: Flat, glistening, finely contoured, translucent, butyrous.
Broth: Turbid with flocculent pellicle and sediment. Slight fluorescence at top.
Litmus milk: Alkaline with slow peptonization.
Potato: Cream colored streak.
Indol not formed.
Nitrates not reduced.
H_2S not formed.
Starch slowly hydrolyzed.
Acid in dextrose, levulose, galactose, sucrose and glycerol.
Aerobic, facultative.
Optimum temperature 20° to 22°C
Habitat: Bacterial halo spot of Rudzer (*Pueraria thimbergiana*).

56. **Phytomonas cannae** (Bryan) Bergey et al. (*Bacterium cannae* Bryan, Jour. of Agr. Research, *21*, 1921, 2nd page 153; Bergey et al., Manual, 1st ed., 1923, 188; *Pseudomonas cannae* Stapp., Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 65.)

Rods with rounded ends: 0.5 to 0.7 by 1.0 to 2.0 microns, occurring singly, in pairs and in chains. Motile with one to three polar flagella. Encapsulated. Gram-negative.

Gelatin colonies: Thin, circular, lobate.
Gelatin stab: Thin, white, transparent, slightly rugose, undulate, surface growth. Slow crateriform liquefaction.
Agar colonies: Thin, white, circular, smooth, glistening, semi-transparent, concentric markings.

Agar slant: Filiform, white, moist, shiny, undulate, viscid.

Broth: Slightly turbid, with heavy viscid pellicle and sediment.

Litmus milk: Becoming clear, golden brown, sometimes jelly-like in consistency. Alkaline.

Potato: Scanty, white, moist, shiny, becoming pale brown. Medium becoming gray.

Indol not formed.

Nitrates reduced to nitrites and ammonia.

Starch is hydrolyzed.

Forms H_2S.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Causes "bud rot" in cannas (*Canna indica* L.).

57. **Phytomonas striafaciens** (Elliott) Bergey et al. (*Bacterium striafaciens* Elliott, Jour. Agr. Research, *35*, 1927, 811; Bergey et al., Manual, 3rd ed., 1930, 268.)

Rods with rounded ends, 0.65 by 1.75 microns, occurring singly, in pairs or in short chains. Encapsulated. Motile with polar flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: Liquefied.

Agar colonies: White, ridged, entire.

Agar slant: White, smooth, glistening.

Broth: Turbid.

Litmus milk: Soft curd, peptonized, alkaline.

Potato.

Indol not formed.

Nitrates show slight reduction.

Starch is hydrolyzed.

H_2S is formed.

Acid in dextrose, levulose and sucrose.

Ammonia is formed.

Aerobic, facultative.

Optimum temperature 22°C.

Habitat: Bacterial stripe blight of oats.

58. **Phytomonas lachrymans** (Smith and Bryan) Bergey et al. (*Bacterium lachrymans* Smith and Bryan, Jour. of Agr. Research, *5*, 1915, 465; *Bacillus burgeri* Potebnia, Khartov Prov. Agr. Exp. Sta., No. 1, 1915, 37; Bergey et al., Manual, 1st ed., 1923, 184; *Pseudomonas lachrymonas* Ferraris, Trattato di Patologia e Terapia vegetale, *1*, 1926, 132.)

Short rods with rounded ends, 0.8 by 1.0 to 2.0 microns, occurring singly or in pairs. Motile with one to five polar flagella. Encapsulated. Gram-negative.

Gelatin stab: Slow liquefaction.

Agar colonies: Small, smooth, slightly convex with opaque center, thin, transparent, entire.
Agar slant: Thin, grayish-white streak.
Broth: Turbid.
Litmus milk: Becoming alkaline.
Potato: Scanty, white growth.
Indol not formed.
Nitrates not reduced.
Blood serum not liquefied.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 25° to 27°C.
Habitat: Causes "angular leaf spot" of cucumber.

59. **Phytomonas panici** (Elliott) Bergey et al. (*Bacterium panici* Elliott, Jour. Agr. Research, *26*, 1923, 151; *Pseudomonas panici* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 27; Bergey et al., Manual, 3rd ed., 1930, 269.)

Rods, with rounded ends, 0.45 to 0.9 by 1.5 to 3.0 microns, occurring singly and in pairs, occasionally in short chains. Encapsulated. Motile with one to three polar flagella. Gram-negative.
Gelatin colonies: Circular, raised, granular, entire.
Gelatin stab: Liquefaction crateriform.
Agar colonies: Circular, white, slightly iridescent, smooth, shining, raised.
Agar slant: Moderate, filiform, white, raised, translucent, butyrous to viscid.
Broth: Turbid with thin pellicle.
Litmus milk: Alkaline. Reduction of litmus.
Potato: Moderate, flat, filiform, light cinnamon-buff to tawny olive, smooth, butyrous.
Indol not formed.
Nitrates are reduced.
Starch is hydrolyzed.
No acid in carbohydrate media.
H_2S is formed.
Ammonia is formed.
Aerobic, facultative.
Optimum temperature.
Habitat: Bacterial leaf stripe of Proso millet.

60. **Phytomonas apii** (Jagger) Bergey et al. (*Pseudomonas apii* Jagger, Jour. of Agr. Research, *21*, 1921, 186; Bergey et al., Manual, 1st ed., 1923, 184; *Pseudomonas jaggeri* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 210; *Bacterium jaggeri* Elliott, Bacterial Plant Pathogens, 1930, 142; Not *Bacterium apii* Brizi, Lavori e Relaz. della Reg. Staz. di Patol. Veg. Rome, Gennio-Giugo, 1896, 15; nor *Bacillus apii* Migula, System der Bakterien, 1900, 778.)

Rods: 0.4 to 0.8 by 1.7 microns, occurring singly. Motile with one to several polar flagella. Gram-negative.

Gelatin stab: Liquefied.

Agar colonies: Grayish-white, circular, shiny, flat to slightly raised, becoming granular, entire.

Agar slant: Abundant, grayish-white.

Broth: Marked turbidity with ropy sediment.

Litmus milk: No coagulation. Becoming alkaline with peptonization.

Potato: Abundant, grayish-white to yellowish.

Indol not formed.

Nitrates not reduced.

Acid in dextrose and sucrose.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: The cause of bacterial "leaf spot" disease of celery, *Apium graveolens* L.

61. **Phytomonas aptata** (Brown and Jamieson) Bergey et al. (*Bacterium aptatum* Brown and Jamieson, Jour. of Agr. Research, *1*, 1913, 206; Bergey et al., Manual, 1st ed., 1923, 184; *Pseudomonas aptata* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 99.)

Rods with rounded ends, 0.6 by 1.2 microns, grouped singly, in pairs and in chains. Motile with one or several polar flagella. Rods white. Gram-negative.

Gelatin colonies: Circular, whitish, glistening, smooth.

Gelatin stab: Crateriform liquefaction.

Lactose agar slant: Abundant, becoming azure blue.

Broth: Turbidity slight, with green fluorescence.

Litmus milk: Blue ring at surface. Alkaline.

Potato: Abundant, flat, smooth, white, glistening.

Starch not hydrolyzed.

Nitrates not reduced.

Indol is formed.

H_2S is formed.

Ammonia is produced.

Aerobic, facultative.

Optimum temperature 27° to 28°C.

Habitat: Disease of sugar beet and nasturtium leaves.

62. **Phytomonas tabaci** (Wolf and Foster) Bergey et al. (*Bacterium tabacum* Wolf and Foster, Science, N. S. *46*, 1917, 362; also Jour. of Agr. Research, *12*, 1918, 449; Bergey et al., Manual, 1st ed., 1923, 185; *Pseudomonas tabaci* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten *2*, 5 Aufl., 1928, 266.)

Rods with rounded ends, 1.2 by 3.3 microns, occurring singly and in short chains. Motile with a polar flagellum. Gram-negative.

Gelatin stab: Slow liquefaction.

Agar colonies: Grayish-white, raised, smooth, moist, entire.
Agar slant: Filiform.
Broth.
Litmus milk: Alkaline, reduced.
Potato.
Indol.
Nitrates not reduced.
Blood serum not liquefied.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 25° to 28°C.
Habitat: Causes "wildfire" in tobacco.

63. **Phytomonas maculicola** (McCullough) Bergey et al. (*Bacterium maculicolum* McCullough, U. S. Dept. Agr., Bur. Plant. Ind. Bul. 225, 1911, 14; *Pseudomonas maculicolum* Stevens, The Fungi which cause Plant Disease, 1913, 28; Bergey et al., Manual, 1st ed., 1923, 189.)

Short rods: 0.8 to 0.9 by 1.5 to 2.4 microns, with rounded ends, occurring singly, in pairs and in long chains. Motile with one to five polar flagella. Gram-negative.
Gelatin colonies: Small, white, entire to fimbriate.
Gelatin stab: Crateriform liquefaction. Slight fluorescence.
Agar colonies: Small, white, circular, smooth, undulate margin.
Broth: Turbid with white pellicle, becoming slightly greenish.
Litmus milk: Becoming alkaline.
Potato.
Slight indol formation.
Nitrates not reduced.
No acid in carbohydrate media.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 25°C
Habitat: Produces brownish to purplish-gray "spots" on cauliflower leaves.

64. **Phylomonas seminum** (Cayley) Bergey et al. (*Pseudomonas seminum* Cayley, Jour. of Agric. Sci., *8*, 1917, 461; *Bacterium seminum* Stevenson, Foreign Plant Diseases, U. S. Dept. Agr., 1926, 141; Bergey et al., Manual, 3rd ed., 1930, 272.)

Large rods: 1 by 4 to 5 microns, sometimes in chains, containing spore-like bodies. Motile with a polar flagellum. Gram-positive.
Gelatin colonies.
Gelatin stab: Napiform liquefaction.
Agar colonies: Opaque, white, circular.
Agar slant: Opaque, white streak.
Broth: Cloudy to turbid, with a pellicle.
Litmus milk: Reduction of litmus. The medium assumes an apricot color, changing to deep cherry and finally to deep wine color.

Potato: Good growth of creamy consistency, becoming contoured. A faint pink tinge over the surface of the growth.

Indol.

Nitrates reduced to nitrites.

Starch not hydrolyzed.

Acid but no gas in dextrose and sucrose. No acid in lactose.

Anaerobic, facultative.

Optimum temperature 25°C.

Habitat: Causes a disease of peas.

65. **Phytomonas rubrilineans** Lee et al. (Lee, Purdy, Barnum, and Martin, Hawaiian Sugar Planters' Assoc. Bull., 1925, 1–99; *Pseudomonas rubrilineans* Stapp, Sorauer's Handbuch der Pflanzen-Krankheiten, *2*, 5 Aufl., 1928, *Bacterium rubrilineans* Elliott, Bacterial Plant Pathogens, 1930, 195.)

Rods: 0.7 to 1.67 microns, occurring singly or in pairs. Without capsules. Motile with one to three polar flagella. Gram-negative.

Gelatin colonies: Small circular, slightly buff in color, translucent.

Gelatin stab: Liquefied.

Agar colonies: Circular, smooth, shiny light buff, margin entire, flatly conic.

Agar slant: Filiform, flatly convex, shiny, smooth, opalescent. Light buff, of rather slimy consistency.

Broth: Moderate clouding in 24 hours producing a pellicle and a viscid sediment.

Litmus milk: A clearing occurs. Reduction of litmus, but little change in reaction.

Potato: Filiform, smooth, opaque, with dull luster. Medium darkened.

Indol not produced.

Nitrates reduced to nitrites.

Starch: Slight diastatic action.

Acid but no gas in dextrose. No acid or gas in sucrose and lactose.

Anaerobic, facultative.

Optimum temperature.

Habitat: Causes the "red stripe" disease of sugar cane.

66. **Phytomonas intybi** Swingle. (Phytopath., *15*, 1925, 730; *Bacterium intybi* Elliott, Bacterial Plant Pathogens, 1930, 142.)

Rods: Motile with polar flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: Liquefied.

Agar colonies.

Agar slant.

Broth.

Litmus milk.

Potato.

Indol not produced.

Nitrates reduced with gas formation.

Starch not hydrolyzed.
Anaerobic, facultative.
Optimum temperature 20° to 30°C.
Habitat: Causes a center rot or wilt of chicory (*Cichorium intybus*).

67. **Phytomonas tumefaciens** (Smith and Townsend) Bergey et al. (*Bacillus ampelopsorae* Trevisan, Saccardo, Sylloge Fungorum, *8*, 1889, 983; *Bacillus ampelopsorae* Trev. *emend.* Cavara, Staz. Sperim. Agrar. Ital. Moderna, *30*, 1897, 483; *Bacterium tumefaciens* Smith and Townsend, Science, N. S., *25*, 1907, 672; *Pseudomonas tumefaciens* Stevens, The Fungi which cause Plant Disease, 1913, 35; Bergey et al., Manual, 1st ed., 1923, 189; *Polymonas tumefaciens* Lieske, Cent. f. Bakt., I Abt., 1928, 108.)

Small rod, usually 0.6 to 1.0 by 1.2 to 1.5 microns in the infected plant and 0.7 to 0.8 by 2.5 to 3.0 microns in agar, occurring singly and in pairs. Motile with one to three polar flagella. Rods white. Gram-negative.
Gelatin colonies: Small, white, dense, circular.
Gelatin stab: No liquefaction.
Agar colonies: Small, white, circular, smooth, glistening, translucent, entire.
Agar slant: Moderate, filiform.
Broth: Slightly turbid, with thin pellicle.
Litmus milk: Slowly coagulated. Litmus reduced. Alkaline.
Potato: Grayish, smooth, moist, glistening.
Indol formed in slight amount.
Nitrates not reduced.
No gas in carbohydrate media.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 25° to 28°C.
Habitat: Causes "crown gall" formation on Paris daisy (*Chrysanthemum frutescens*) and cross inoculable on a number of other plants.

68. **Phytomonas agropyri** (O'Gara) Bergey et al. (*Aplanobacter agropyri* O'Gara, Phytopathology, *6*, 343; Bergey et al., Manual, 1st ed., 1923, 190.)

Short rods with rounded ends, 0.4 to 0.6 by 0.6 to 1.1 microns, occurring singly and occasionally in short chains. Non-motile. Gram-negative.
Gelatin stab: No liquefaction.
Agar colonies: Small, globular.
Agar slant: Slow, opaque, beaded, viscid.
Broth: Turbid.
Litmus milk: Slight coagulation
Potato: Papillate, viscid.
Indol not formed.
Nitrates not reduced.
Blood serum not liquefied.
Starch not hydrolyzed.
Aerobic, facultative.

Optimum temperature 25° to 28°C.
Habitat: Causes disease of wheat grass.

69. **Phytomonas solaniolens** (Paine) Bergey et al. (*Pseudomonas solaniolens* Paine, Rpt. Int. Conf. Phytopath. and Econom. Entom. (Holland), 1923, 77; Bergey et al., Manual, 3rd ed., 1930, 274.)

Small oval rod: Motile with a very long polar flagellum. Gram-negative.
Gelatin colonies: Round, iridescent.
Gelatin stab: Not liquefied.
Agar colonies.
Agar slant.
Broth.
Litmus milk: Curd with no sign of digestion.
Potato: Pale buff colored growth, no change in medium.
Indol.
Nitrates not reduced.
Starch: Action feeble.
Acid but no gas in dextrose. No acid or gas in sucrose and lactose.
Aerobic, facultative.
Optimum temperature 20° to 30°C.
Habitat: Causes the "internal rust spot" disease of potato.

70. **Phytomonas cichori** Swingle. (Phytopath., *15*, 1925, 730; *Bacterium cichori* Elliott, Bacterial Plant Pathogens, 1930, 112.)

Rods: Motile with polar flagella. Gram-negative.
Gelatin colonies.
Gelatin stab: Not liquefied.
Agar colonies.
Agar slant.
Broth.
Litmus milk: Unchanged.
Potato.
Indol not produced.
Nitrates not reduced.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 20° to 30°C.
Habitat: Causes a center rot or wilt of chicory (*Cichorium intybus*).

71. **Phytomonas dissolvens** Rosen. (*Pseudomonas dissolvens* Rosen, Phytopath., *12*, 1922, 497; Rosen, Phytopath., *16*, 1926, 264; *Bacterium dissolvens* Rosen, 1926, *ibid.*; *Aplanobacter dissolvens* Rosen, 1926, *ibid.*)

Rods: 0.5 to 0.9 by 0.7 to 1.2 microns, occurring singly, in pairs, and occasionally in short chains. Motile with a single polar flagellum. Gram-negative.
Gelatin stab: No liquefaction.

Agar colonies: Circular, white, opaque, glistening, entire.
Agar slant: White, glistening.
Broth: Turbid.
Litmus milk: Coagulated. Peptonized.
Potato.
Indol formed.
Nitrates reduced.
Ammonia formed.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: The cause of corn stalk rot.

72. **Phytomonas savastanoi** (Erw. Smith) Bergey et al. (*Bacillus oleae tuberculosis* Savastano, Atti R. Accad. Naz. Lincei Rend. Cl. Sci. Fis. Mat. e. Nat., *5*, 1889, 92; *Bacterium savastanoi* Erw. Smith, U. S. Dept. Agr., Plant Ind. Bul. 131, 1908, 31; *Pseudomonas savastanoi* Stevens, The Fungi which cause Plant Disease, 1913, 33; Bergey et al., Manual, 1st ed., 1923, 190.)

Note: Related names of doubtful import. (See Erw. Smith, U. S. Dept. Agr., Plant Ind. Bul. 131, 1908.) *Bacterium oleae* Arcangeli, Instit. Bot. della R. Univ. di Pisa, Ricerche e Lavoi, fasc. *1*, 1886, 109; *Bacillus prillieuxianus* Trevisan, I Generi e le Specie delle Batteriacee, 1889, 19; *Bacillus oleae*, Trevisan, Saccardo, Sylloge Fungorum, *8*, 1889, 982.

Rods, white with rounded ends, 0.4 to 0.5 by 1.2 to 3.0 microns, occurring singly and occasionally in short chains. Motile with one to several polar flagella. Gram-negative.

Gelatin colonies: Undulate, erose, frilled, lobed or incised.
Gelatin stab: No liquefaction.
Agar colonies: Small, translucent, becoming white, circular, flat, smooth, glistening, entire.
Agar slant.
Broth: Slightly turbid, with thin pellicle and grayish sediment.
Litmus milk: Translucent, alkaline.
Potato: A soluble brown pigment is formed.
Slight indol formation.
Nitrates not reduced.
Acid formed in dextrose, galactose and sucrose.
Starch hydrolyzed to amylodextrin and maltose.
Aerobic, facultative.
Optimum temperature 22° to 25°C.
Habitat: The cause of "tubercle" formation on olive trees.

73. **Phytomonas mori** (Boyer and Lambert) Bergey et al. (*Bacterium mori* Boyer and Lambert, Compt. Rend. Acad. Sci. Paris, *117*, 1893, 342; *Bacterium mori* Boyer and Lambert *emend.* Erw. Smith, Science, N. S., *31*, 1910, 792; *Pseudomonas mori* Stevens, The Fungi which cause Plant Disease, 1913, 30; Bergey et al., Manual, 1st ed., 1923, 191.)

Rods: 0.9 to 1.3 by 1.8 to 4.5 microns, with rounded ends. Motile with one to seven polar flagella. The rods are white. Gram-negative.

Gelatin colonies: Flat, white, irregularly circular, lobate-erose.

Gelatin stab: No liquefaction.

Agar colonies: Circular, white, smooth, flat, entire, becoming undulate.

Agar slant: Dull, white, flat, spreading.

Broth: Turbid, with pellicle.

Litmus milk: No coagulation; strongly alkaline.

Potato: Moderate, dirty-white, flat, smooth, glistening.

Indol formation absent or feeble.

Nitrates not reduced.

No gas in carbohydrate media.

Starch slowly hydrolyzed.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Associated with "blight" on mulberry.

74. **Phytomonas andropogoni** (Smith) Bergey et al. (*Bacterium andropogoni* Erw. Smith, Bacteria in Relation to Plant Diseases, Carnegie Institution, Washington, D. C., *2*, 1911, 63; Elliott and Smith, Jour. of Agr. Research, *38*, 1929, 1; *Pseudomonas andropogoni* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 27; Bergey et al., Manual, 3rd ed., 1930, 276.)

Rods: 0.4 to 0.8 by 1.3 to 2.5 microns, occurring singly and in pairs. Motile with one to several polar flagella. Gram-negative.

Gelatin colonies: Small with raised center, smooth, glistening.

Gelatin stab: No liquefaction.

Agar colonies: Circular, white, finely granular, glistening, slightly raised, entire.

Agar slant: Moderate, filiform, smooth, glistening, white, contoured, viscid.

Broth: Turbid with thin pellicle and viscid sediment.

Litmus milk: Peptonized. Alkaline.

Potato: Flat, gray, smooth, glistening, viscid.

Indol not produced.

Nitrates not reduced.

Acid is formed in dextrose, xylose and arabinose.

Partial hydrolysis of starch.

H_2S not formed.

Aerobic, facultative.

Optimum temperature 22° to 30°C.

Habitat: Bacterial stripe disease of sorghum.

75. **Phytomonas loehnisii** (Kalantarian) Bergey et al. (*Bacterium löhnisi* Kalantarian, Cent. f. Bakt., II Abt., *65*, 1925, 330; Bergey et al., Manual, 3rd ed., 1930, 276.)

Rods, with rounded ends, 0.5 by 0.8 to 2.0 microns, occurring singly and in pairs. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Small, circular, grayish white, raised, glistening.
Gelatin stab: No liquefaction.
Potato agar colonies: Circular, grayish-white, watery, glistening.
Potato agar streak: White, filiform, glistening.
Broth: Turbid with grayish pellicle.
Litmus milk: Peptonized, alkaline.
Potato: Slight, deep brown streak.
Indol is formed.
Nitrates not reduced.
No gas in carbohydrate media.
Starch not hydrolized.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Bud rot of cotton plant.

76. **Phytomonas sojae** (Wolf) Burkholder. (*Bacterium sojae* Wolf, Phytopath., *10*, 1920, 119; Burkholder, Phytopath, *16*, 1926, 922; *Pseudomonas sojae* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Auf., 1928, 174.)
Note: Elliott, Bacterial Plant Pathogens, 1930, 133 considers *Phytomonas sojae* a synonym of *Phytomonas glycinea*.
Rods: 0.8 to 0.9 by 1.2 to 2.6 microns, occurring singly and in short chains. Motile with one to five polar flagella. Gram-negative.
Gelatin stab: No liquefaction.
Agar colonies: Circular, smooth, glistening, entire, white, viscid.
Agar slant: Filiform, spreading, raised, opaque, glistening.
Broth: Turbid, with delicate pellicle.
Litmus milk: Slight reduction, alkaline.
Potato: Grayish-white, spreading.
Indol not formed.
Nitrates not reduced.
Starch slightly hydrolyzed.
No acid or gas in carbohydrate media.
Aerobic.
Optimum temperature 20°C.
Habitat: Bacterial blight of soy bean (*Soja max*).

77. **Phytomonas alboprecipitans** (Rosen) Bergey et al. (*Pseudomonas alboprecipitans*, Ann. Missouri Bot. Garden, *9*, 1922, 383; *Bacterium alboprecipitans* Elliott, Bacterial Plant Pathogens, 1930, 89; Bergey et al., Manual, 3rd ed., 1930, 277.)
Narrow rods, solitary or in pairs, 0.5 to 0.8 by 1.5 to 2.0 microns. Capsules present. Motile with a polar flagellum. Gram-negative.
Gelatin colonies: Circular, margins entire, glistening, white with a bluish luster, entire.
Gelatin stab: Not liquefied.

Agar colonies: White circular, smooth, margin entire with a colorless zone, sticky in consistency. Large, measuring up to 6 mm. in diameter.

Agar slant: Filiform, raised, glistening, smooth, opaque to creamy white.

Broth: Marked clouding with pellicle and a flocculent sediment.

Litmus milk: Slightly alkaline. Peptonized.

Potato: Growth glistening, brown, and sticky.

Indol not produced.

Nitrates reduced to nitrites.

Ammonia produced.

H_2S not produced.

Starch hydrolyzed.

Blood serum not liquefied

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Pathogenic on foxtail and various grasses, including most of the common cereals.

78. **Phytomonas rhizogenes** Riker et al. (Riker, Banfield, Wright, Keitt and Sagen, Jour. Agric. Research, *41*, 1930, 507; *Bacterium rhizogenes* Riker et al., *ibid.*; *Pseudomonas rhizogenes* Riker et al., *ibid.*)

Rods: 0.4 by 1.4 microns, occurring singly. Motile by a polar flagellum. Encapsulated. Gram negative.

Gelatin stab: Not given.

Agar colonies: Circular, smooth, convex, finely granular, entire translucent to gray.

Agar slant: Gray, smooth, entire.

Broth: Turbid with heavy pellicle.

Litmus milk: Acid. Slow reduction.

Potato: Moderate, watery growth.

Indol is not formed.

Nitrates are not reduced.

Acid formed in dextrose, galactose, mannose, arabinose, xylose, maltose, lactose, rhamnose, salicin and erythritol. No action on levulose, sucrose, raffinose, melezitose, starch, dextrin, inulin, aesculin, dulcitol, or mannitol.

Starch is not hydrolized.

Ammonia is formed.

Aerobic.

Optimum temperature 20-28°C.

Habitat: Causes infections having root on apple trees.

79. **Phytomonas michiganensis** (Erw. Smith) Bergey et al. (*Bacterium michiganense* Erw. Smith, Science, N. S., *31*, 1910, 794; *Aplanobacter michiganense* Erwin Smith, Bacteria in Relation to Plant Diseases, *3*, 1914, 161; *Pseudomonas michiganense* Stevens, The Fungi Which Cause Plant Disease, 1913, 30; Bergey et al., Manual, 1st ed., 1923, 191.)

Short, yellow rods: 0.35 to 0.4 by 0.8 to 1.0 micron. Non-motile. Gram-positive.

Gelatin colonies: Slow development.
Gelatin stab: Slow liquefaction.
Agar colonies: Small, circular, yellow.
Agar slant: Pale yellow, somewhat slimy.
Broth: Slightly turbid, with slimy sediment.
Litmus milk: Slowly coagulated; becoming paler.
Potato: Pale yellow streak, becoming bright yellow.
Indol not formed.
Nitrates not reduced.
No gas in carbohydrate media.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: The cause of bacterial "canker" in tomato.

80. **Phytomonas insidiosa** (McCulloch) Bergey et al. (*Aplanobacter insidiosum* McCulloch, Phytopathology, *15*, 1925, 497; Jour. Agr. Research, *33*, 1926, 493; *Bacterium insidiosum* Stapp, Sorauer's Handbuch der Pflanzenkrankheiten, *2*, 5 Aufl., 1928, 178; Bergey et al., Manual, 3rd ed., 1930, 278.)

Rods: 0.4 to 0.5 by 0.7 to 1.0 micron, occurring singly and in pairs. Non-motile. Encapsulated. Gram-positive.

Gelatin stab colonies: Small, circular, pale yellow, becoming Naples yellow, opaque.

Gelatin stab: Slight, crateriform liquefaction, with yellow sediment.

Agar colonies: Slow development. The rate of growth is increased by the addition of dextrose, potato, or whey to the agar.

Agar slant: Growth, thin, colorless, becoming pale yellow. More abundant growth on dextrose, yeast, whey, alfalfa, or potato agar.

Broth: Turbid.

Litmus milk: Yellow surface layer in four to five days. Reduction.

Potato: Pale yellow streak, becoming Naples yellow, with dark blue granules.

Indol not formed.
Nitrates not reduced.
Acid in dextrose, galactose, sucrose and glycerol.
H_2S not formed.
Aerobic, facultative.
Optimum temperature 22° to 25°C.
Habitat: Bacterial wilt and root rot of alfalfa.

81. **Phytomonas stewartii** (Erw. Smith) Bergey et al. (Sweet corn bacillus, Stewart, Bull. 130, N. Y. Agr. Exp. Sta., 1897; *Pseudomonas stewarti* Smith, Proc. Amer. Assoc. Adv. Sci., *47*, 1898, 422; *Bacterium stewarti* Erw. Smith, Bacteria in Relation to Plant Diseases, *3*, 1914, 89; *Aplanobacter stewarti* McCulloch, Phytopath., *8*, 1918, 440; Bergey et al., Manual, 1st ed., 1923, 192.)

Yellow rods: 0.65 to 0.85 by 2.5 to 3.5 microns, with rounded ends, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Irregular, granular, entire.

Gelatin stab: Dense, dry, rough, buff-yellow surface growth. No liquefaction.

Agar colonies: Small, circular, yellow.

Agar slant: Smooth, translucent, yellow, shiny, becoming dry and raised.

Broth: Slightly turbid, with yellowish-white sediment.

Litmus milk: Slightly acid, becoming alkaline. Yellow sediment.

Potato: Moderate yellow.

Indol not formed.

Nitrates not reduced.

No gas in carbohydrate media.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: The causative agent in Stewart's disease (blight) of sweet corn (maize).

82. **Phytomonas rathayi** (Erw. Smith) Bergey et al. (*Aplanobacter rathayi* Erw. Smith, Science, N. S., *38*, 1913, 926; Erw. Smith, Bacteria in Relation to Plant Diseases, *3*, 1914, 155; Bergey et al., Manual, 1st ed., 1923, 192; *Bacterium rathay* Stapp, Sorauer's Handbuch Pflanzenkrankheiten, *2*, 5 Auf., 1928, 36.)

Yellow rods: 0.6 to 0.75 by 1.5 microns, with rounded ends, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: No colonies developed.

Gelatin stab. Not liquefied.

Agar colonies: No surface colonies formed. Deep colonies develop very slowly; yellow in color.

Agar slant. Limited, yellow growth

Broth: Clear.

Litmus milk: Yellow ring. Chrome-yellow sediment. Slightly acid, becoming alkaline.

Potato: Yellow, raised, rugose.

Indol not formed.

Nitrates not reduced.

No gas in carbohydrate media.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 25°C.

Habitat: The causative agent of Rathay's disease of orchard grass (*Dactylis glomeratus*).

83. **Phytomonas stizolobii** (Wolf) Bergey et al. (*Aplanobacter stizolobii* Wolf, Phytopath., *10*, 1920, 73; *Bacterium stizolobii* McCulloch, Phytopath., *18*, 1928, 460; Bergey et al., Manual, 3rd ed., 1930, 280.)

Rods: 0.6 to 0.7 by 1.0 to 1.6 microns occurring singly. Non-motile. Encapsulated. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Circular, smooth, white, raised, opaque, undulate.

Agar slant: Filiform, with whitish edges; contoured.

Broth: Slight turbidity.

Litmus milk: Slightly alkaline. Casein precipitated.

Potato: White, glistening, spreading.

Indol not formed.

Nitrates not reduced.

No acid or gas in carbohydrate media.

Starch not hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Bacterial leaf spot of velvet bean (*Stizolobium deeringianum*).

84. **Phytomonas teutlia** (Metcalf) Bergey et al. (*Bacterium teutlium* Metcalf, Nebr. Agric. Exp. Sta. Rept., *17*, 1903, 69; *Aplanobacter teutlium* Erw. Smith, An Introduction to Bacterial Diseases of Plants, 1920, 474; Bergey et al., Manual, 3rd ed., 1930, 280.)

Rods: 0.5 to 0.8 by 1.5 to 2.0 microns. Non-motile. Gram-positive.

Gelatin colonies: Circular, slow growing, margins entire, somewhat opaque, porcelaneous.

Gelatin stab: Not liquefied.

Agar colonies: Slow growing, circular, translucent, not viscid, margins entire, diameter seldom over 0.5 mm., porcelaneous.

Agar slant: Filiform, porcelaneous streak.

Broth: Slight clouding, with slight sediment.

Litmus milk: No change.

Potato: No visible growth on the surface of the potato.

Indol: No growth in peptone solution.

Nitrates: No growth.

Starch.

Anaerobic, facultative.

Optimum temperature 15° to 22°C.

Habitat: Causes a soft rot of sugar-beet.

TRIBE VI. LACTOBACILLEAE COMMITTEE S. A. B., 1920.

Rods, often long and slender. Gram-positive. Non-motile. Without endospores. Always produce lactic acid from carbohydrates. When gas is formed it is CO_2 without H_2. A number of these organisms are somewhat thermophilic. As a rule, microaerophilic. Surface growth on media is poor.

Genus X. Lactobacillus *Beijerinck, 1901.*

Generic characters are those of the tribe.

The type species is *Lactobacillus caucasicus* Beijerinck.

Key to the species of genus **Lactobacillus.***

The key of the species has been rearranged so as to eliminate unknown characters as far as possible. Although the separation upon the basis of usual origin is not necessarily true in all cases it is used because it groups the various types. Many species now grouped together can only be separated by a study of the description of the individual species. Even this is impossible since certain descriptions are inclusive, while others are exclusive.

A. Produce only traces of by-products other than lactic acid.
- a. Usually of animal or animal products origin.
  - b. Acid in sucrose.
    1. *Lactobacillus caucasicus.*
    2. *Lactobacillus lactis.*
    3. *Lactobacillus acidophilus.*
    4. *Lactobacillus lactisacidi.*
    5. *Lactobacillus casei.*
    6. *Lactobacillus thermophilus.*
  - bb. No action on sucrose.
    7. *Lactobacillus helveticus.*
    8. *Lactobacillus bulgaricus.*
  - bbb. Action on sucrose unknown.
    9. *Lactobacillus boas-oppleri.*
- aa. Usually of plant or soil origin.
  - b. Acid in lactose.
    - c. Acid in arabinose.
      10. *Lactobacillus plantarum.*
      11. *Lactobacillus cucumeris.*
      12. *Lactobacillus wortmannii.*
      13. *Lactobacillus busaeasiaticus.*
      14. *Lactobacillus pentosus.*
      15. *Lactobacillus arabinosus.*
    - cc. No action on arabinose.
      16. *Lactobacillus listeri.*
    - ccc. Action on arabinose unknown.
      17. *Lactobacillus pabuliacidi.*
  - bb. No action on lactose.
    - c. Acid in arabinose.
      18. *Lactobacillus berolinensis.*
    - cc. No action on arabinose.
      - d. Acid in sucrose.
        19. *Lactobacillus leichmanii.*
        20. *Lactobacillus beijerinckii.*

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* Key to genus rearranged by Dr. C. S. Pederson, N. Y. Agr. Exp. Station, Geneva, N. Y.

dd. No action on sucrose.

21. *Lactobacillus delbrueckii.*

B. Produce considerable amounts of by-products other than lactic acid (CO_2, alcohol and acetic acid).

a. Usually of animal origin.

b. Acid in arabinose.

22. *Lactobacillus brevis.*

bb. No action on arabinose.

23. *Lactobacillus longus.*

bbb. Action on arabinose unknown.

24. *Lactobacillus acidophil-aerogenes.*

aa. Usually of plant or soil origin.

b. Acid in arabinose.

c. Acid in raffinose.

25. *Lactobacillus mannitopoeus.*
26. *Lactobacillus pastorianus.*
27. *Lactobacillus wehmeri.*
28. *Lactobacillus buchneri.*
29. *Lactobacillus hayduckii.*

cc. No action on raffinose.

30. *Lactobacillus pentoaceticus.*
31. *Lactobacillus fermentatus.*
32. *Lactobacillus panis.*
33. *Lactobacillus lycopersici.*

bb. No action on arabinose.

34. *Lactobacillus intermedius.*
35. *Lactobacillus lindneri.*
36. *Lactobacillus gayonii.*
37. *Lactobacillus gracilis.*

bbb. Action on arabinose unknown.

38. *Lactobacillus fermenti.*
39. *Lactobacillus soyae.*

1. **Lactobacillus caucasicus** Beijerinck. (Prototype: *Dispora caucasica* Kern, Biol. Zent., *2*, 1882, 135; later in Bull. de la Soc. Imp. des naturalistes de Moscou, *56*, 1882, 168) (*Bacillus caucasicus* Beijerinck, Archives néerlandaises des sciences exactes et naturelles, *23*, 1889, 428; Beijerinck, Archives néerlandaises des sciences exactes et naturelles, Háarlem, Sér. 2, *7*, 1901, 212.)

Probable synonyms: *Bacillus lebenis* Rist and Khouri, Ann. d. l'Institut Pasteur, *16*, 1902, 65; *Bacterium mazuni* Weigmann, Gruber and Huss, Cent. f. Bakt., II Abt., *19*, 1907, 70.

Rods: 0.3 to 1.0 by 5.0 to 6.0 microns, often occurring in long chains. Show glistening points at the poles. Non-motile. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Agar colonies: Small, flat, grayish, circular, undulate. Deep colonies are fimbriate.

Agar slant: Limited, grayish streak.
Lactose broth: Turbid.
Litmus milk: Acid, with soft, creamy curd.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose and lactose. Forms mostly laevo-lactic acid. Forms 1.2 to 1.6 per cent lactic acid in milk.
Microaerophilic.
Optimum temperature 37° to 40°C.
Habitat: Isolated from "kefir."

2. **Lactobacillus lactis** (Orla-Jensen) *comb nov.* (*Thermobacterium lactis* Orla-Jensen, The Lactic Acid Bacteria, 1919, 164.)
Rods: Long forms with a tendency to grow into threads, often strongly curling. Occur singly or in pairs in young vigorous cultures. Generally contain volutin grains.
Milk: Acid produced followed by clot in one to four days. 1.7 per cent acid produced
Acid produced from levulose, dextrose, mannose, galactose, sucrose, maltose, and lactose. Glycerol, xylose, arabinose, rhamnose, sorbitol, mannitol, raffinose, inulin, dextrin and starch not fermented. Salicin may or may not be fermented.
Forms levo lactic acid with only a trace of other by products.
Minimum temperature: 18° to 22°C.
Maximum temperature: 50°C.
Optimum temperature: 40°C.
Habitat: Isolated from milk and cheese.

3. **Lactobacillus acidophilus** (Moro) Holland. (*Bacillus acidophilus* Moro, Jahrbuch f. Kinderheilkunde, *52*, 1900, 38; Wien. Med. Wochenschr., 1900; Holland, Jour. Bact., *5*, 1920, 215.)
Rods, rather slender, frequently with tapering ends, 4.0 to 5.0 microns in length occurring singly and in short chains. Non-motile. Gram-positive, older cultures may also show Gram-negative forms.
Gelatin colonies: Slow development, gray, fimbriate.
Gelatin stab: Scanty growth.
Agar colonies: Thin, irregular, translucent, fimbriate margin.
Agar slant: Filiform, smooth, slimy, translucent, fimbriate margin.
Broth: Slightly turbid, with gray sediment.
Litmus milk: Acid, usually with soft coagulum, after 48 hours.
Potato: No visible growth.
Indol not formed.
Nitrates probably not reduced.
Acid formed in dextrose, levulose, galactose, mannose, maltose, lactose, sucrose and raffinose. Some cultures also ferment dextrin. Cultures give off odor of acetic acid.
Microaerophilic.

Optimum temperature 37°C.

Habitat: Intestinal canal.

Rahe (Jour. of Bact., *3*, 1918, 420) distinguishes four types of *L. acidophilus* on the basis of carbohydrate fermentation:

Lactobacillus acidophilus

Type	*Maltose*	*Dextrose*	*Lactose*	*Sucrose*	*Raffinose*
A	+	+	+	+	+
B	+	+	+	+	−
C	+	+	−	+	−
D	+	+	−	−	−

4. **Lactobacillus lactis-acidi** (Leichmann) Holland. (*Bacillus lactis acidi* Leichmann, Cent. f. Bakt., II Abt., *2*, 1896, 283; Holland, Jour. Bact., *5*, 1920, 215.)

Rods: 0.5 to 0.8 by 0.8 to 1.2 microns, occurring singly and in chains. Non-motile. Gram-positive.

Gelatin stab.

Agar colonies.

Agar slant: Soft, grayish, transparent, filiform.

Broth.

Litmus milk: Unchanged.

Potato.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, maltose, lactose, sucrose, dextrin, and smaller amounts in raffinose, mannitol and quercit. Laevo-lactic acid is formed.

Microaerophilic.

Optimum temperature 40°C.

Habitat: Isolated from milk.

5. **Lactobacillus casei** (Orla-Jensen) Holland. (*Bacillus* α v. Freudenreich, Ann. d. Micrographie, *2*, 1890, 266; also, Landw. Jahrb. d. Schweiz., 1891, 16; *Bacillus casei* α v. Freudenreich and Thöni, Landw. Jahrb. d. Schweiz, 1904, 526; also Orla-Jensen, Cent. f. Bakt., II Abt., 13, 1904, 609; *Caseobacterium vulgare* Orla-Jensen, Maelkeri-Bakteriologie, 1916; 35; *Streptobacterium casei* Orla-Jensen, The Lactic Acid Bacteria, 1919, 166; Holland, Jour. Bact., *5*, 1920, 223.)

Rods: Short or long chains of short or long rods. Non-motile. Gram-positive.

Milk: Acid with coagulation in 3 to 5 days or longer, may become slimy. Forms about 1.5 per cent lactic acid.

Attacks casein and therefore important in cheese ripening.

Acid formed from dextrose, levulose, mannose, galactose, maltose, lactose, mannitol, and salicin. May or may not ferment sucrose. Mostly dextro-lactic acid formed though a small amount of levo-lactic acid may be formed. Only lactic acid produced with a trace of other by-products.

Microaerophilic.
Minimum temperature 10°C.
Optimum temperature 30°C.
Maximum temperature 37° to 40°C. and with some strains 45°C.
Habitat: Isolated from milk and cheese.

6. **Lactobacillus thermophilus** Ayers and Johnson. (Jour. of Bact. 1924, 291.)

Rods: 0.5 by 3.0 microns. Non-motile. Gram-positive.
Gelatin stab: No liquefaction.
Agar colonies: Small, pin-point colonies.
Agar slant: Slight, translucent growth.
Broth: Turbid.
Litmus milk: Acid.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Forms acid in dextrose, lactose, sucrose, starch and trace in glycerol.
Microaerophilic.
Optimum temperature 50° to 62.5°C.
Habitat: Pasteurized milk. Causes pin-point colonies on agar plates.

7. **Lactobacillus helveticus** (Orla-Jensen) Bergey et al. (*Bacillus* ε v. Freudenreich, Cent. f. Bakt., II Abt., *1*, 1895, 173; Also Landw. Jahrb. d. Schweiz, 1895, 211; *Bacillus casei* ε v. Freudenreich and Thöni, Landw. Jahrb. d. Schweiz, 1904, 526; Also Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 609; *Caseobacterium* ε Orla-Jensen, Cent. f. Bakt., II Abt., *22*, 1909, 337; *Thermobacterium helveticum* Orla-Jensen, Maelkeri Bakteriologie, 1916, 35; also The Lactic Acid Bacteria 1919, 164; Bergey et al., Manual, 2nd ed., 1925, 184.)

Rods: 0.7 to 0.9 by 2.0 to 6.0 microns, occurring singly and in chains. Non-motile. Gram-positive.

Whey gelatin colonies: Does not grow readily at temperatures required for incubation of gelatin.

Lactose agar colonies: Small, grayish, viscid.
Litmus milk: Acid, with coagulation, may become slimy.
Potato: No growth.
Indol not formed.
Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, mannose, maltose, lactose and smaller amounts in dextrin. The lactic acid is inactive.

Microaerophilic.
Minimum temperature 20° to 22°C.
Optimum temperature 40° to 42°C.
Maximum temperature 50°C.
Habitat: Isolated from sour milk and cheese.

8. **Lactobacillus bulgaricus** (Grigoroff) Holland. (*Bacillus bulgaricus* Grigoroff, Revue Médicale de la Suisse Romande, *25*, 1905, 714; Holland, Jour. Bact., *5*, 1920, 215.)

Probable synonyms: *Bacillus acetogenes α* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 49; *Bacillus acetogenes β* Distaso, loc. cit., 51; *Bacillus acetogenes proteiformis* Distaso, loc. cit., 52; *Bacillus acetogenes exilis* Tissier, *Bacillus paraexilis* Distaso, loc. cit. 56; *Bacillus dimorphus* Distaso, *loc. cit.*, 55; *Streptobacillus longus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 439; *Bacterium casei filans* Gorini, Rend. R. Acc. Lincei, *21*, 1912, 472; Cent. f. Bakt., II Abt., 37, 1913, 1.

Rods: 1.0 by 2.0 microns, often occurring in long chains. Non-motile. Gram-positive, older cultures show Gram-negative forms.

Grows on media containing milk, whey or malt.

Whey gelatin: No liquefaction.

Whey agar colonies: Circular to irregular, grayish-white, filamentous.

Whey: Turbid, with grayish-white sediment.

Litmus milk: Acid, with soft creamy curd, in 24 hours.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, lactose and mannitol.

Forms 2.7 to 3.7 per cent lactic acid in milk. The lactic acid formed is either inactive or laevo-rotary. Also forms a small quantity of volatile acid.

Microaerophilic.

Optimum temperature 40° to 45°C.

Habitat: Isolated from "yoghurt."

Rahe (Jour. of Bact., *3*, 1918, 420) distinguishes four types of *L. bulgaricus* on the basis of carbohydrate fermentation:

Lactobacillus bulgaricus

Type	*Maltose*	*Dextrose*	*Lactose*	*Sucrose*	*Raffinose*
A.	−	+	+	−	−
B.	−	+	+	−	+
C.	−	+	+	+	−
D.	−	+	+	+	+

9. **Lactobacillus boas-oppleri** Bergey et al. (Milchsaurebacillus, Boas and Oppler, Deutsche med. Wochenschr., *21*, 1895, 73; Diagnostik und Therapie d. Magenkrankheiten, II Teil, 1907, 265; Bergey et al., Manual, 1st ed., 1923, 243.)

Rods: 1.0 by 6.0 to 8.0 microns, occurring in pairs and in chains. Non-motile. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Milk agar colonies: Small, gray, granular.

Litmus milk: Acid with coagulation.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose and lactose. Forms 1.0 per cent laevo-lactic acid in milk.
Microaerophilic.
Optimum temperature 40°C. Grows at 37°C.
Habitat: Found in normal gastric contents, but especially in gastric carcinoma.

10. **Lactobacillus plantarum** (Orla-Jensen) Bergey et al. (*Streptobacterium plantarum* Orla-Jensen, The Lactic Acid Bacteria, Copenhagen, 1919, 174; Bergey et al., Manual, 1st ed., 1923, 250.)
Rods: 0.8 to 1.0 by 3.0 to 8.0 microns, occurring singly and in short chains, with rounded ends. Non-motile. Gram-positive.
Gelatin colonies: Very small, translucent.
Gelatin stab.
Agar slant.
Broth: Turbid.
Litmus milk: Acid; usually coagulated.
Potato.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, levulose, galactose, mannose, arabinose, maltose, lactose, sucrose, dextrin, inulin, salicin, raffinose, mannitol and sorbitol.
Inactive lactic acid formed.
Microaerophilic.
Optimum temperature 37°C.
Habitat: Sour dough; cheese; pickled cabbage.

11. **Lactobacillus cucumeris** Bergey et al. (*Bacillus cucumeris fermentati* Henneberg, Zeitschr. f. Spiritusindustrie, *26*, 1903, 22; Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 1st ed., 1923, 250.)
Rods: 0.2 to 1.6 by 1.5 to 2.0 microns, occurring singly and in short chains. Non-motile. Gram-positive.
Agar colonies.
Agar slant.
Broth.
Litmus milk: Acid.
Potato.
Indol not formed.
Nitrates not reduced
Acid formed in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, raffinose, trehalose and mannitol. Small amounts of acid are formed in dextrin. Forms 1.0 per cent lactic acid in mash.
Microaerophilic.
Optimum temperature 34°C.
Habitat: Isolated from naturally fermenting pickles.

12. **Lactobacillus wortmannii** (Henneberg) Bergey et al. (*Bacillus wortmannii* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 3rd ed., 1930, 288.)

Rods: 0.5 by 1.4 microns, occurring singly, in pairs, and in short chains.

Gelatin stab.

Agar colonies: Small, white.

Agar slant: Filiform, white streak.

Broth.

Litmus milk: Acid.

Potato.

Indol not formed.

Nitrates not reduced.

Acid in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, dextrin, raffinose, trehalose, mannitol and α-methyl-glucoside.

Microaerophilic.

Optimum temperature 34°C.

Habitat: Isolated from sour mash in distillery.

13. **Lactobacillus busaeasiaticus** (Tschekan) Bergey et al. (*Bacterium busae asiaticae* Tschekan, Cent. f. Bakt., II Abt., *78*, 1929, 89; Bergey et al., Manual, 3rd ed., 1930, 288.)

Rods: 0.35 to 0.4 by 1.7 to 4.0 microns, occurring singly, in pairs and short chains. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Wort agar slant: Good growth. Best growth in stab.

Broth.

Litmus milk: Slow coagulation (18 days).

Potato.

Indol.

Nitrates.

Can derive nitrogen from peptone, phaseolin, alanin, gelatin, albumin, casein, lucein and asparagin in the foregoing order.

Acid in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, and traces in dextrin, inulin, amylum and mannitol. No action on glycerol, dulcitol, α-methyl-glucoside or ethyl alcohol. Maximum acidity produced 1.1 per cent. Inactive lactic acid formed.

Grows within the range of pH 3.7 to 8.2; optimum pH 6.4 to 6.7.

Anaërobic, facultative.

Optimum temperature 32° to 42°C.

Habitat: Isolated from "busa," an alcoholic beverage made in Turkestan

14. **Lactobacillus pentosus** Fred, Peterson and Anderson. (Jour. of Biol. Chem., *48*, 1921, 385; Jour. Biol. Chem., *53*, 1922, 111.)

Rods: 0.5 to 0.8 by 1.25 to 3.0 microns, with blunt ends. Occurs singly, in pairs and in chains. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Yeast water agar colonies: Small, gray.

Yeast water agar slant: Scant, gray, beaded growth.
Broth.
Litmus milk: Soft curd with extrusion of whey. Litmus reduced.
Potato.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, galactose, mannose, lactose, maltose, sucrose arabinose, xylose, salicin, raffinose, mannitol and α-methyl glucoside. Strains vary in action on dulcitol. Inactive lactic acid formed.
Growth range pH 3.5 to 9.4.
Thermal death-point 60° to 65°C.
Microaerophilic.
Optimum temperature 30°C.
Habitat: Sauerkraut.

15. **Lactobacillus arabinosus** Fred, Peterson and Anderson. (Jour. of Biol. Chem., *48*, 1921, 385.)
Rods: 0.5 to 0.6 by 1.2 to 2.0 microns, with blunt ends. Occur singly, in pairs and in chains. Non-motile. Gram-positive.
Gelatin stab: No liquefaction.
Yeast water agar colonies: Small, gray.
Yeast water agar slant: Scant, gray, beaded growth.
Broth.
Litmus milk: Soft curd with extrusion of whey. Litmus reduced.
Potato.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, levulose, galactose, mannose, arabinose, melezitose, lactose, maltose, sucrose, mannitol, salicin and raffinose. Inactive lactic acid formed.
Growth range pH 3.5 to 9.4.
Microaerophilic.
Optimum temperature 30°C.
Habitat: Sauerkraut.

16. **Lactobacillus listeri** (Henneberg) Bergey et al. (*Bacillus listeri* Henneberg, Zeitschr. f. Spiritusindustrie, *26*, 1903, 22; Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 1st ed., 1923, 248.)
Probable synonyms: *Bacillus aderholdi* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 154; *Bacillus maercki* Henneberg, *ibid*; *Bacillus leichmanni II* Henneberg, *ibid*.
Rods: 0.7 by 1.4 to 2.8 microns, occurring singly, in pairs and in chains. Non-motile. Gram-positive.
Gelatin colonies.
Gelatin stab.
Agar colonies: Small, white, circular.
Agar slant.

. Broth.
Litmus milk: Acid.
Potato.
Indol not formed.
Nitrates probably not reduced.
Acid formed in dextrose, levulose, galactose, maltose, lactose, sucrose, raffinose, trehalose, mannitol, and smaller amounts in dextrin. Forms 1.1 per cent lactic acid in mash.
Microaerophilic.
Optimum temperature 34°C.
Habitat: Isolated from sour mash in distillery.

17. **Lactobacillus pabuliacidi** Bergey et al. (*Bacillus pabuli acidi II* Weiss, Inaugural Dissertation, Göttingen, 1898; Cent. f. Bakt., II Abt., *5*, 1899, 599; Bergey et al., Manual, 1st ed., 1923, 247.)
Note: Weiss considers this species to be closely related to *Bacillus* α of v. Freudenreich (*Lactobacillus casei*).
Rods, occurring singly and in long chains. Non-motile. Gram-positive
Gelatin colonies.
Gelatin stab: Slightly arborescent growth in stab in old cultures.
Agar colonies: Small, transparent.
Agar slant: Grayish.
Broth: Slightly turbid.
Litmus milk: Acid, with coagulation.
Potato: No visible growth.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, levulose, maltose, lactose, and sucrose with a small amount in glycerol and starch.
Microaerophilic.
Optimum temperature 34° to 40°C.
Habitat: Isolated from beet mash and from cheese.

18. **Lactobacillus berolinensis** Bergey et al. (*Saccharobacillus pastorianus* var. *berolinensis* Henneberg. Cent. f. Bakt., II Abt., *8*, 1902, 184; Bergey et al., Manual, 1st ed., 1923, 246.)
Rods: 0.5 to 1.6 by 3.0 to 6.0 microns, occurring singly and in chains. Non-motile. Gram stain not recorded.
Agar colonies: Small, grayish, flat.
Agar slant: Slight, grayish growth on surface and in stab.
Broth: Slightly turbid.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, levulose, galactose, maltose and arabinose. Forms 1.0 per cent lactic acid in mash.

Microaerophilic.

Optimum temperature 21° to 24°C.

Habitat: Isolated from spoiled beer.

19. **Lactobacillus leichmannii** Bergey et al. (*Bacillus leichmanni I* Henneberg, Zeitschr. f. Spiritusindustrie, *26*, 1903, 22; see Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 2nd ed., 1925, 180.)

Rods: 0.6 by 2.0 to 4.0 microns, occurring singly and in short chains. The cells show two or more deeply-staining granules. Non-motile. Gram positive.

Gelatin stab: No liquefaction.

Agar colonies: Small, whitish to transparent, filamentous.

Agar slant: Limited, grayish streak.

Broth: Turbid.

Litmus milk: Acid; coagulated. Litmus reduced.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, maltose, sucrose, trehalose, and slight amounts in galactose, mannitol and a-methyl-glucoside. Lactose, raffinose, arabinose, rhamnose, dextrin and inulin not fermented. Forms 1.3 per cent lactic acid in mash.

Microaerophilic.

Optimum temperature 45°C.

Habitat: Isolated from sour mash in distillery, and from fermenting milk.

20. **Lactobacillus beijerinckii** (Henneberg) Bergey et al. (*Bacillus beijerinckii* Henneberg, Zeitschr. f. Spiritusindustrie, *26*, 1903, 22; see Cent. f. Bakt., II Abt., *11*, 1903, 154, Bergey et al., Manual, 1st ed., 1923, 248.)

Rods: 0.5 by 1.4 to 3.2 microns, occurring singly, occasionally in pairs and chains. Non-motile. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Agar colonies: Small, transparent with grayish center.

Agar slant: Grows best in stab. Surface growth limited, transparent.

Broth: Slightly turbid.

Litmus milk: Acid; soft coagulation produced.

Potato: No visible growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, sucrose, maltose and to a less degree in dextrin.

Microaerophilic.

Optimum temperature 35° to 45°C.

Habitat: Isolated from sour potato mash in distillery.

21. **Lactobacillus delbrueckii** (Leichmann) Holland. (*Bacillus delbrückii* Leichmann, Cent. f. Bakt., II Abt., *2*, 1896, 281; *Thermobacterium cereale* Orla-Jensen, The Lactic Acid Bacteria, 1919; Holland, Jour. Bact., *5*, 1920, 215.)

Probable synonym: *Bacillus leichmanni III*, Cent. f. Bakt., II Abt., *11*, 1903, 154.

Rods: 0.5 to 0.8 by 2.0 to 7.0 microns, occurring singly and in short chains. Non-motile. Gram-positive.

Gelatin colonies: Small, gray, circular.

Gelatin stab: No growth on the surface. Good development in the stab.

Agar colonies: Small, flat, crenated.

Agar slant: Narrow, translucent, soft, grayish streak.

Broth: Slightly turbid.

Litmus milk: Unchanged.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, maltose, sucrose and dextrin. Laevo-rotary lactic acid is formed. Forms 1.6 per cent acid in mash.

Microaerophilic.

Optimum temperature 30° to 35°C.

Habitat: Isolated from sour potato mash in distillery.

22. **Lactobacillus brevis** (Orla-Jensen) *comb. nov.* (*Bacillus* γ v. Freudenreich, Landw. Jahrb. d. Schweiz., 1891, 22; *Bacillus casei* γ v. Freudenreich and Thöni, Landw. Jahrb. d. Schweiz, 1904, 526; Also Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 604; *Betabacterium breve* Orla-Jensen, The Lactic Acid Bacteria, 1919, 175.)

Rods: 0.7 to 1.0 by 2.0 to 4.0 microns with rounded ends, occurring singly and in short chains. Non-motile. Gram-positive.

Milk: Acid produced but no clot except with some freshly isolated strains.

Does not attack casein as a rule.

Is able to utilize lactate of lime as a source of carbon.

Acid formed from arabinose, levulose, dextrose, mannose, galactose, maltose and lactose. Does not attack sucrose, raffinose, salicin or the alcohols. Xylose may or may not be fermented.

Produces gas and other by-products besides lactic acid. Inactive lactic acid formed with sometimes a surplus of dextro lactic acid.

Optimum temperature 30°C. Growth poor below 15° and above 37°C.

Maximum temperature 38°C.

Habitat: Isolated from milk, kefir and cheese.

23. **Lactobacillus longus** (Orla-Jensen) *comb. nov.* (*Bacillus* δ v. Freudenreich, Cent. f. Bakt., II Abt., *1*, 1895, 173; Also Landw. Jahrb. d. Schweiz, 1895, 211; *Bacillus casei* δ v. Freudenreich and Thöni, Landw. Jahrb. d.

Schweiz, 1904, 526; Also Orla-Jensen, Cent. f. Bakt., II Abt., *13*, 1904, 609; *Betabacterium longum* Orla-Jensen, The Lactic Acid Bacteria, 1919, 174.)

Rods: Cells generally longer than those of *Lactobacillus brevis*. Irregular swelling found on cells of some strains. Non-motile. Gram-positive.

Milk: Growth in milk poor. A little acid is produced but milk is not clotted.

Acid formed from levulose, glucose, mannose, galactose, sucrose, maltose, lactose and raffinose. Does not attack arabinose, salicin or the alcohols. Xylose may or may not be fermented.

Produces gas and other by-products besides lactic acid. Inactive lactic acid produced, with sometimes a surplus of dextro lactic acid.

Minimum temperature: 18°C.

Maximum temperature: 45°C.

Optimum temperature: A few degrees below 45°C.

Habitat: Isolated from milk, kefir, and cheese.

24. **Lactobacillus acidophil-aerogenes** (Torrey and Rahe) Bergey et al. (*Bacillus acidophil-aerogenes* Torrey and Rahe, Jour. of Infectious Diseases, *17*, 1915, 437; Bergey et al., Manual, 1st ed., 1923, 254.)

Rods: 0.8 by 1.5 to 5.0 microns, occurring singly and in chains. Non-motile. Gram-positive.

Gelatin colonies.

Gelatin stab.

Agar colonies.

Agar slant.

Lactose broth: Turbid.

Litmus milk: Acid, usually with coagulation.

Potato.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, maltose, lactose, sucrose and raffinose. Gas is formed.

Microaerophilic.

Optimum temperature 37°C.

Habitat: Intestinal canal.

Rahe (Jour. of Bact., *3*, 1918, 405) distinguishes eight different types of *L. acidophil-aerogenes* on the basis of fermentation of carbohydrates:

L. acidophil-aerogenes A.

(Gas in all test substances)

L. acidophil-aerogenes G.	*L. acidophil-aerogenes H.*
(No gas in lactose)	(No gas in sucrose)

L. acidophil-aerogenes B.
(No gas in raffinose)

L. acidophil-aerogenes C.
(No growth in raffinose)

L. acidophil-aerogenes D.
(No gas in raffinose or lactose)

L. acidophil-aerogenes E.
(No growth in raffinose or lactose)

L. acidophil-aerogenes F.
(No growth in raffinose, lactose or sucrose)

Lactobacillus acidophil-aerogenes

Type	*Maltose*	*Dextrose*	*Lactose*	*Sucrose*	*Raffinose*
A	Gas	Gas	Gas	Gas	Gas
B	Gas	Gas	Gas	Gas	Acid
C	Gas	Gas	Gas	Gas	—
D	Gas	Gas	Acid	Gas	Acid
E	Gas	Gas	—	Gas	—
F	Gas	Gas	—	—	—
G	Gas	Gas	Acid	Gas	Gas
H	Gas	Gas	Gas	Acid	Gas

25. **Lactobacillus mannitopoeus** (Müller-Thurgau) Pederson. (*Bacterium mannitopoeum* Müller-Thurgau, Cent. f. Bakt., II Abt., *20*, 1908, 396; *ibid.*, *36*, 1912, 129; *ibid.*, *48*, 1917, 1; Pederson, New York Agr. Exp. Sta. Tech. Bulls. 150 and 151, 1929.)

Rods: 0.6 to 0.7 by 1.5 to 2.0 microns, occurring singly and in short chains. Non-motile. Gram-positive.

Gelatin stab: Growth uniform from top to bottom, filiform. No liquefaction.

Agar colonies: Subsurface, circular, white, edges entire. Lens shaped colonies common.

Agar slant: Scanty filiform growth.

Broth: Rapid clouding, viscid sediment.

Litmus milk: Unchanged.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, arabinose, xylose, maltose, lactose, sucrose, raffinose, and melezitose. Lactic and acetic acid are

formed in dextrose, levulose and arabinose, ethyl alcohol and carbon dioxide in dextrose, and mannitol in levulose.

Microaerophilic.

Optimum temperature 30° to 37°C.

Habitat: Isolated from wine and tomato catsup.

26. **Lactobacillus pastorianus** (Henneberg) Bergey et al. (*Saccharobacillus pastorianus* Henneberg, Cent. f. Bakt., II Abt., *8*, 1902, 184; Bergey et al., Manual, 1st ed., 1923, 246.)

Rods: 0.9 to 1.0 by 2.0 to 21.0 microns, occurring singly and in chains. Non-motile. Gram-positive.

Gelatin colonies.

Gelatin stab.

Agar colonies: Small, gray, raised, crenated.

Agar slant: Slow growth.

Broth: Good growth in yeast extract.

Litmus milk: Acid with very slow coagulation.

Potato.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, arabinose, maltose, sucrose, dextrin, raffinose, trehalose and mannitol. Forms 1.5 per cent acid in mash. Also forms CO_2 and alcohol, lactic, formic, and acetic acid.

Microaerophilic.

Optimum temperature 27° to 33°C.

Habitat: Isolated from sour beer, and from distillery yeast.

27. **Lactobacillus wehmeri** (Henneberg) Bergey et al. (*Bacillus wehmeri* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 1st ed., 1923, 249.)

Rods: 0.5 by 1.0 to 1.4 microns, occurring singly and in chains. Non-motile. Gram-positive.

Gelatin colonies.

Gelatin stab.

Agar colonies: Small, white, circular.

Agar slant.

Broth.

Litmus milk: Acid.

Potato.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, dextrin, raffinose and mannitol. Gas is formed and 1.3 per cent lactic acid in mash and 2.7 per cent alcohol.

Microaerophilic.

Optimum temperature 39° to 40°C.

Habitat: Isolated from molasses.

28. **Lactobacillus buchneri** (Henneberg) Bergey et al. (*Bacillus buchneri* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 1st ed., 1923, 251.)

Rods: 0.35 by 0.7 to 1.4 microns, occurring singly, in pairs and in chains. Non-motile. Gram-positive.

Gelatin colonies.

Gelatin stab.

Agar colonies: White to yellowish, adherent.

Agar slant.

Broth.

Litmus milk.

Potato.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, dextrin, raffinose and mannitol. Gas is formed. Forms 1.3 per cent lactic acid in mash and 2.7 per cent alcohol.

Microaerophilic.

Optimum temperature 39° to 40°C.

Habitat: Isolated from sour mash.

29. **Lactobacillus hayduckii** (Henneberg) Bergey et al. (*Bacillus haydučki* Henneberg, Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 1st ed., 1923, 253.)

Rods: 0.5 by 1.4 to 4.2 microns, occurring singly, in pairs and chains. Non-motile. Gram-positive.

Gelatin colonies.

Gelatin stab.

Agar colonies: Circular, whitish.

Agar slant.

Broth.

Litmus milk.

Potato.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, arabinose, maltose, sucrose, dextrin, raffinose and mannitol. Gas is formed. Forms 1.5 per cent lactic acid in mash and 2.9 per cent alcohol.

Microaerophilic.

Optimum temperature 25°C.

Habitat: Isolated from sour mash.

30. **Lactobacillus pentoaceticus** Fred, Peterson and Davenport. (Jour. Biol. Chem., *39*, 1919, 358, Peterson and Fred, *ibid.*, 42, 1920, 273.)

Rods, 0.6 to 0.7 by 1.6 to 2.5 microns, with blunt ends, occurring singly and in short chains, occasionally as filaments. Gram-positive.

Gelatin stab: Growth uniform along line of inoculation. No liquefaction.

Agar colonies: Small, grayish, smooth, entire.
Agar slant: Scant, bladed, glistening.
Broth: Slowly becoming turbid.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
The aldohexoses are fermented with the formation of lactic acid, ethyl alcohol, carbon dioxide and small quantities of acetic acid. Dextrose and galactose are fermented at approximately the same rate, mannose less actively. All strains ferment levulose, sucrose, mannitol, arabinose, xylose and methyl glucoside. The action on lactose is variable. Do not ferment melezitose, dulcitol or isodulcitol. pH range 3.5 to 8.8. Ethyl alcohol is one of the principal products in the fermentation of dextrose while acetic acid is one of the principal products in the fermentation of levulose and xylose. Inactive lactic acid produced.
Microaerophilic.
Optimum temperature, 30° to 35°.
Habitat: Soil, manure, ensilage, sauerkraut.

31. **Lactobacillus fermentatus** Bergey et al. (*Bacillus brassicae fermentatae* Henneberg, Zeitschr. f. Spiritusindustrie, *26*, 1903; Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 1st ed., 1923, 249.)
Rods: 0.6 to 1.4 by 1.6 to 2.4 microns, occurring singly, in pairs and short chains. Non-motile. Gram-positive.
Gelatin colonies.
Gelatin stab.
Agar colonies: Flat, circular, whitish, moist, with raised center.
Agar slant: Whitish, spreading.
Broth.
Litmus milk: Slightly acid
Potato.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, levulose, galactose, arabinose, maltose, sucrose, and smaller amount in mannitol. Gas is formed. Forms 1.46 per cent lactic acid in mash and 2.4 per cent alcohol.
Microaerophilic.
Optimum temperature 24° to 38°C.
Habitat: Isolated from sauer kraut.

32. **Lactobacillus panis** Bergey et al. (*Bacillus panis fermentati* Henneberg, Zeitschr. f. Spiritusindustrie, *26*, 1903; Cent. f. Bakt., II Abt., *11*, 1903, 154; Bergey et al., Manual, 1st ed., 1923, 251.)
Rods: 0.5 to 0.8 by 2.8 to 4.8 microns, occurring singly, in pairs and chains. Non-motile. Gram-positive.
Gelatin colonies.
Gelatin stab.

Agar colonies: Grayish-white, flat, irregular.
Agar slant.
Broth.
Litmus milk: Acid.
Potato.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, levulose, arabinose, maltose and sucrose. Gas is formed. Forms 0.9 per cent lactic acid in mash and 2.6 per cent alcohol.
Microaerophilic.
Optimum temperature: 25° to 38°C.
Habitat: Isolated from sour dough.

33. **Lactobacillus lycopersici** Mickle. (Abs. Bact., *8*, 1924, 403; Mickle and Breed, New York Agr. Exp. Sta. Tech. Bull. 110, 1925; Pederson, *ibid.*, Tech. Bulls. 150 and 151, 1929.)
Rods: 0.3 to 0.5 by 1.5 to 5.0 microns, occurring singly and in long filaments, granulated. Non-motile. Gram-positive.
Gelatin colonies.
Tomato gelatin stab: Growth uniform, filiform. No liquefaction.
Agar colonies: Punctiform with smooth surface and entire edges. Subsurface colonies sometimes lens shaped.
Agar slant.
Broth: Slowly becoming turbid.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrate not reduced.
Acids formed in dextrose, levulose, galactose, mannose, arabinose, xylose, maltose. Lactic and acetic acid formed from dextrose, levulose and arabinose, ethyl alcohol and carbon dioxide from dextrose and mannitol from levulose.
Microaerophilic.
Optimum temperature 30° to 37°C.
Habitat: Isolated from fermented catsup, from canned tomato pulp and tomatoes.

34. **Lactobacillus intermedius*** (Müller-Thurgau and Osterwalder) Bergey et al. (*Bacterium intermedium* Müller-Thurgau and Osterwalder, Cent. f. Bakt., II Abt., *48*, 1917, 1; Bergey et al., Manual, 3rd ed., 1930, 295.)
Rods: 0.8 to 1.0 by 1.2 to 1.5 microns, occurring singly or in short filaments. Non-motile. Gram-positive.

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* This might well be considered a synonym of *Lactobacillus gayonii*.

Gelatin colonies: White.
Gelatin stab.
Agar colonies: White, circular.
Agar slant.
Broth.
Litmus milk.
Potato.
Indol.
Nitrates.
Acid formed in dextrose, levulose, galactose, xylose, maltose, lactose, sucrose, raffinose. Lactic and acetic acid and carbon dioxide are formed from dextrose, levulose, xylose and other sugars. It forms a little ethyl alcohol from dextrose and mannitol from levulose.
Facultative anaerobe.
Optimum temperature.
Habitat: Wine.

35. **Lactobacillus lindneri** (Henneberg) Bergey et al. (*Bacillus lindneri* Henneberg, Wochenschr. für Brauerei, *18*, 1901, No. 30; Cent. f. Bakt., II Abt., *8*, 1902, 184; Bergey et al., Manual, 1st ed., 1923, 245.)
Rods: 0.3 to 0.8 by 1.7 to 2.0 microns, occurring singly, in pairs and in chains. Non-motile. Gram-positive.
Gelatin colonies: No growth.
Gelatin stab: No growth.
Agar colonies: Circular, grayish.
Agar slant: Isolated grayish colonies.
Broth: Clear.
Litmus milk: No growth.
Potato: No growth.
Acid formed in dextrose, levulose, maltose and sucrose.
Forms lactic and acetic acid equal to 0.9 per cent of lactic acid. Forms 1.5 per cent alcohol.
Indol not formed.
Nitrates not reduced.
Microaerophilic.
Optimum temperature 27° to 32°C.
Habitat: Isolated from spoiled beer, and from distillery yeast.

36. **Lactobacillus gayonii** (Müller-Thurgau and Osterwalder) Pederson. (*Bacterium gayonii* Müller-Thurgau and Osterwalder, Cent. f. Bakt., II Abt., *48*, 1917, 1; Pederson, New York Agr. Exp. Sta. Tech. Bulls. 150 and 151, 1929.)
Rods: 0.5 to 0.8 by 1 to 3 microns, occurring singly and in short filaments. Non-motile. Gram-positive.
Tomato gelatin stab: Growth uniform, filiform. No liquefaction.
Agar colonies: Circular, white, with smooth surface and entire edges. Lens shaped colonies occur.
Agar slant: Light transparent growth after several days.
Broth: Slowly becoming turbid.

Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, levulose, galactose, mannose, maltose, lactose, sucrose and raffinose. Lactic and acetic acid are formed from dextrose and levulose, ethyl alcohol and carbon dioxide from dextrose and mannitol from levulose.
Microaerophilic.
Optimum temperature 30° to 37°C.
Habitat: Wine, canned tomatoes.

37. **Lactobacillus gracilis** (Müller-Thurgau) Bergey et al. (*Bacterium gracile* Müller-Thurgau, Cent. f. Bakt., II Abt., *20*, 1908, 396; *ibid.*, *36*, 1912, 129; *ibid.*, *48*, 1917, 1; Bergey et al., Manual, 3rd ed., 1930, 297.)
Rods: 0.4 to 0.6 by 0.7 to 1.0 micron, occurring singly or in short chains. Non-motile. Gram-positive.
Gelatin colonies: Round, white.
Gelatin stab: No liquefaction. No growth.
Agar colonies.
Agar slant.
Broth.
Litmus milk.
Potato.
Indol.
Nitrates.
Acid formed in dextrose, levulose and galactose. Lactic and acetic acids and carbon dioxide are formed from dextrose and levulose, ethyl alcohol from dextrose and mannitol from levulose.
Facultative anaerobe.
Optimum temperature 22° to 26°C.
Habitat: Wine.

38. **Lactobacillus fermenti** Beijerinck. (Arch. Néerland. des sciences exactes et naturelles, Sér. *11*, 7, 1901, 212; Smit, Zeitschr. f. Garungsphysiol., *5*, 1916, 273.)
Rods: 0.5 to 1.0 by 3.0 to 15.0 microns. Non-motile. Gram-positive.
Agar colonies.
Agar slant.
Broth.
Litmus milk: Acid.
Potato.
Indol not formed.
Nitrates not reduced.
Reduction of litmus, methylene blue, indigo carmine, sodium thiosulphate. NaS_2O_3 is reduced to H_2S.
Acid and gas formed in dextrose, levulose, maltose and sucrose; less

actively in lactose. A part of the levulose and sucrose are reduced to mannitol.

Microaerophilic.

Optimum temperature 41° to 42°C.

Habitat: In most compressed yeast factories.

39. **Lactobacillus soyae** (Saito) Bergey et al. (*Bacterium soyae* Saito, Cent. f. Bakt., II Abt., *17*, 1907, 20; Bergey et al., Manual, 1st. ed., 1923, 251.)

Rods, with slightly pointed ends, occurring singly, in pairs and short chains. Non-motile. Gram-positive.

Gelatin colonies: Small, circular, grayish-white.

Gelatin stab: No surface growth. Filiform growth in stab.

Agar colonies.

Agar slant: Thin, shiny, translucent, soft, glistening, somewhat bluish-iridescent.

Broth: No growth.

Litmus milk: Acid.

Potato: Porcelain white, smooth, glistening, slightly granular.

Indol not formed.

Nitrates not reduced.

Soya extract is fermented with gas formation, the gas consisting entirely of CO_2. Alcohol and lactic acid are also formed.

Microaerophilic.

Optimum temperature 37°C.

Habitat: Isolated from soya mash.

TRIBE VII. PROPIONIBACTERIEAE BERGEY ET AL., 1930.

Non-motile, gram-positive rods, growing under anaerobic conditions in neutral media as short rods, and under aerobic conditions as long, irregular rod-shaped cells. Ferment lactic acid, carbohydrates and polyalcohols with the formation of propionic and acetic acids and carbon dioxid. Complex organic nitrogen compounds are required for development. Generally catalase is formed.

A single genus is recognized.

Genus XI. Propionibacterium *Orla-Jensen, 1909.*

(Cent. f. Bakt., II Abt., *22*, 1909, 337.)

Generic characters are those of the tribe.

The type species is *Propionibacterium freudenreichii* van Niel.

Key to the species of the genus Propionibacterium.

1. Do not attack sucrose and maltose.
   - A. Do not attack lactose. Nitrates reduced.
     - 1. *Propionibacterium freudenreichii.*
   - AA. Attack lactose. Nitrates not reduced.

2. *Propionibacterium shermanii.*

2. Attack sucrose and maltose.
   A. Attack the polysaccharides, as starch, dextrin and glycogen
      3. *Propionibacterium technicum.*
   AA. Do not attack the polysaccharides.
      B. Attack xylose and arabinose. Nitrates reduced.
         4. *Propionibacterium pentosaceum.*
      BB. Do not attack xylose and arabinose. Nitrates not reduced.
         C. Attack raffinose.
            D. Pigment yellow.
               5. *Propionibacterium raffinosaceum.*
            DD. Pigment red-brown.
               6. *Propionibacterium rubrum.*
         CC. Do not attack raffinose.
            D. Attach mannitol but not sorbitol.
               E. Attack amygdalin and salicin.
                  7. *Propionibacterium peterssonii.*
               EE. Do not attack amygdalin or salicin.
                  8. *Propionibacterium jensenii.*
            DD. Do not attack mannitol but attack sorbitol.
               9. *Propionibacterium thoenii.*

1. **Propionibacterium freudenreichii** van Niel. (*Bacterium acidi propionici a* von Freudenreich and Orla-Jensen, Cent. f. Bakt., II Abt., *17*, 1906, 532; *Bacterium acidi propionici* var. *fuscum* Thöni and Allemann, Cent. f. Bakt., II Abt., *25*, 1910, 29; van Niel, The Propionic Acid Bacteria, Delft, 1928, 161.)

Small spherical cells 0.5 by 0.6 micron, occurring singly and in pairs and in short chains in acid media, resembling streptococci. Non-motile. Gram-positive. Show metachromatic granules with Albert's stain.

Gelatin stab: No liquefaction.

Yeast agar stab culture: Limited surface growth which remains almost colorless.

Yeast-lactate-phosphate solution: Distinctly turbid with grayish to cream, ropy sediment.

Litmus milk: Slight reduction.

Potato: No growth.

Indol not formed.

Nitrates reduced.

Acid in dextrose, mannose, levulose, galactose, arabinose (sl), esculin, glycerol, adonitol, inositol and erythritol.

No acid formed in sucrose, lactose, maltose, trehalose, raffinose, melezitose, dextrin, glycogen, inulin, starch, xylose, rhamnose, salicin, amygdalin, dulcitol, mannitol, sorbitol, perseitol, pectin and xylan.

Acetyl-methyl-carbonol not formed.

Propionic, acetic and small amounts of succinic acid are formed. Also carbon dioxid.

Catalase is formed.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Emmental cheese.

2. **Propionibacterium shermanii** van Niel. (*Bacterium acidi propionici d* Sherman, Jour. of Bact., *6*, 1921, 387; van Niel, The Propionic Acid Bacteria, 1928, 161.)

Short rods, 0.5 by 0.6 micron, occurring singly. Non-motile. Gram positive. Show metachromatic granules.

Gelatin stab: No liquefaction.

Agar slant: Moderate, granular, slightly yellowish growth.

Broth: Moderately turbid with ropy sediment.

Litmus milk: Acid; coagulated. Reduction.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, mannose, arabinose (slight), lactose, esculin, salacin (slight), glycerol, adonitol, inositol, arabatol and erythritol.

No acid found in sucrose, maltose, trehalose, xylose, raffinose, rhamnose, melezitose, glycogen, dextrin, inulin, starch, amygdalin, mannitol, dulcitol, sorbitol, perseitol and pectin.

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Emmental cheese.

3. **Propionibacterium technicum** van Niel. (The Propionic Acid Bacteria, 1928, 164.)

Short rods, 0.5 by 0.6 micron, occurring singly and in pairs. Non-motile. Gram positive. Show metachromatic granules.

Gelatin stab: No liquefaction.

Agar slant: No growth.

Yeast-Lactate-phosphate solution.

Broth: Moderate turbidity with flocculent sediment.

Litmus milk: Slight acidity with coagulation. Slight reduction.

Potato: Moderate growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, mannose, lactose, maltose, sucrose, raffinose, arabinose, starch, dextrin, salacin, esculin, glycogen, glycerol, mannitol, adonitol, inositol, arabitol and erythritol.

No acid formed in xylose, rhamnose, trehalose, melezitose, inulin, dulcitol, sorbitol, perseitol and pectin.

Propionic, acetic and small amounts of succinic acid, are formed. Also CO_2.

Catalase is formed.

Anaerobic.

Optimum temperature 30°C.
Habitat: Emmental cheese.

4. **Propionibacterium pentosaceum** van Niel. (*Bacillus acidi propionici* von Freudenreich and Orla-Jensen, Cent. f. Bakt., II Abt., *17*, 1906, 532; van Niel, The Propionic Acid Bacteria, 1928, 161.)

Short rods, 0.7 by 1.0 microns, occurring singly, in pairs and short chains. In acid media, long irregularly crooked, locally swollen and sometimes branched cells are formed. Non-motile. Gram positive. Show metachromatic granules.

Gelatin stab: No liquefaction.

Yeast agar stab. Considerable surface growth in stab culture, without production of pigment.

Yeast-lactate-phosphate solution: Slight turbidity with heavy, ropy sediment.

Litmus milk: Acidulated and coagulated. Slight reduction.

Potato: No growth.

Indol not formed.

Nitrates reduced.

Acid formed in dextrose, mannose, levulose, galactose, lactose, maltose, sucrose, melibiose, trehalose, raffinose, melezitose, xylose, arabinose, rhamnose, salicin, esculin, amygdalin, glycerol, arabitol, mannitol, adonitol, inositol, sorbitol and trythirtol.

No acid formed in dextrin, glycogen, inulin, dulcitol, perseitol and pectin.

Propionic, acetic and small amounts of succinic acid are formed. Also carbon dioxide.

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Emmental cheese.

5. **Propionibacterium raffinosaceum** Werkman and Kendall. (*Propionibacterium jensenii* var. *raffinosaceum* van Niel, The Propionic Acid Bacteria, 1928, 162; Iowa State College Journal of Science, *6*, 1931, 17.)

Short rods, 0.7 by 1.0 to 1.3 microns, occurring singly and in short chains. Non-motile. Gram positive. Show metachromatic granules.

Gelatin stab: No liquefaction.

Agar slant: Moderately granular, orange-yellow growth.

Broth: Slightly turbid with flaky sediment.

Litmus milk: Slightly acid, coagulated. Reduction complete.

Potato: Moderate orange-yellow growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, mannose, galactose, lactose, maltose,

sucrose, trehalose, raffinose, melezitose, salicin, esculin, glycerol, arabitol, mannitol, adonitol, inositol, erythritol and amygdalin.

No action on dextrin, glycogen, inulin, starch, xylose, arabinose, rhamnose, dulcitol, perseitol melibiose sorbitol or pectin. Acetyl-methyl-carbinol not produced.

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Emmental cheese.

6. **Propionibacterium rubrum** van Niel. (*Bacterium acidi propionici* var. *rubrum* Thönii and Allemann (in part), Cent. f. Bakt., II Abt., *25*, 1910, 8; van Niel, The Propionic Bacteria, 1928, 164.)

Short rods, 0.8 by 1.2 microns, occurring singly and in pairs. Non-motile. Gram positive. Show metachromatic granules.

Gelatin stab: No liquefaction.

Agar slant: Reddish-orange, slightly beaded growth.

Broth: Slight turbidity, with finely flocculent sediment.

Litmus milk: Slight acidity with slow coagulation and slight reduction.

Potato: Moderate, reddish-orange growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, mannose, lactose, raffinose, trehalose, melezitose, amygdalin, esculin, inulin, salicin, starch, glycerol, arabitol, mannitol, adonitol, sorbitol and erythritol.

No acid formed in xylose, arabinose, rhamnose, melibiose, dextrin, glycogen, inulin, starch, dulcitol, perseitol, inositol and pectin.

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Emmental cheese.

7. **Propionibacterium peterssonii** van Niel. (*Bacterium acidi propionici c* Trioli-Petersson, Cent. f. Bakt., II Abt., *24*, 1909, 333; van Niel, The Propionic Acid Bacteria, 1928, 161.)

Short rods, 0.7 by 2.0 to 3.0 microns, occurring singly and in pairs. Non-motile. Gram positive. Show metachromatic granules.

Gelatin stab: No liquefaction.

In stab cultures a cream-yellow surface growth is formed.

Agar slant: Beaded growth.

Broth: Slight turbidity with flaky sediment.

Litmus milk: Slightly acid with very slight coagulation and slight reduction.

Potato: Slight growth.

Indol not formed.

Nitrates not reduced.

Acid is formed from dextrose, levulose, galactose, mannose, lactose,

sucrose, maltose, trehalose, melezitose (slight), amygdalin, salicin, esculin, glycerol, mannitol, adonitol, arabitol, erythritol and inositol.

No acid formed in raffinose, glycogen, dextrin, inulin, starch, xylose, arabinose, rhamnose, melibiose, dulcitol, sorbitol, perseitol, pectin and xylan.

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Emmental cheese.

8. **Propionibacterium jensenii** van Niel. (*Bacterium acidi propionici b.* von Freundenreich and Orla-Jensen, Cent. f. Bakt., II Abt., 1906, 532; van Niel, The Propionic Acid Bacteria, 1928, 161.)

Rods, 0.7 by 1.0 to 1.3 microns, occurring singly. Non-motile. Gram positive.

Gelatin stab: No liquefaction.

In young stab cultures an extensive orange-yellow surface growth is formed, becoming orange in old cultures.

Indol not formed.

Nitrates not reduced.

Acid formed from dextrose, levulose, galactose, mannose, lactose, maltose, sucrose, raffinose (occasionally), esculin, glycerol, mannitol, adonitol, erythritol, inositol and trehalose.

No acid from xylose, arabinose, dextrin, starch, glycogen, inulin, salicin, amygdalin, raffinose, melezitose, melibiose, rhamnose, dulcitol, sorbitol perseitol or pectin.

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Emmental cheese.

9. **Propionibacterium thoenii** van Niel. (*Bacterium acidi propionici* var. *rubrum* Thöni and Allemann (in part), Cent. f. Bakt., II Abt., *25*, 1910, 8; van Niel, The Propionic Acid Bacteria, 1928, 164.)

Short rods, 0.5 by 1.0 to 1.5 microns, occurring in short chains. Non-motile. Gram positive. Show metachromatic granules.

Gelatin stab: No liquefaction.

Agar slant: Coarsely beaded growth.

Broth: Moderate turbidity with ropy sediment.

Litmus milk: Slight acidity with slight coagulation and slight reduction.

Potato: Moderate, red-orange growth.

Indol not formed.

Nitrates not reduced.

Acid formed from dextrose, levulose, galactose, mannose, lactose, sucrose, maltose, trehalose, esculin, salicin, glycerol, arabitol, adonitol, sorbitol, erythritol and inositol (slight).

No acid formed in xylose, arabinose, rhamnose, raffinose, melezitose,

melibiose, dextrin, inulin, starch, amygdalin, glycerol, mannitol, dulcitol, perseitol or pectin.

Acetyl-methyl-carbinol formed from dextrose.

Catalase is formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Emmental cheese.

TRIBE VIII. KURTHIAE TREVISAN, 1889.

Gram-positive rods, growing freely on artificial media. Found in the tissues or intestinal tracts of animals.

A. Do not attack carbohydrates. Facultative anaerobic.
Genus XII. *Kurthia*, p. 327.
B. Do attack certain carbohydrates. Strictly aerobic.
Genus XIII. *Listerella*, p. 328.

Genus XII. **Kurthia** *Trevisan, 1885.*

Long rods occurring in evenly curved chains. Gram-positive. Motile. Proteus-like growth on media. Carbohydrates and gelatin not attacked. Hydrogen sulphid not formed.

The type species is *Kurthia zopfii* (Kurth) Trevisan.

1. **Kurthia zopfii** (Kurth) Trevisan. (*Bacterium zopfii* Kurth, Bericht. d. Deutsch. Botan. Gesellschaft, *1*, 1883, 97; Trevisan, Atti della Accademia Fisio-medico-statistica in Milano, ser. 4, *3*, 1885, 85; *Zopfius zopfii* Wenner and Rettger, Jour. of Bact., *4*, 1919, 334.)

Rods: 0.8 by 3.5 microns, with rounded ends, occurring in long curved chains. Motile with peritrichous flagella. Gram-positive.

Gelatin colonies: Radiate, filamentous, gray.

Gelatin stab: Arborescent growth in stab. No liquefaction.

Agar colonies: Fimbriate.

Agar slant: Spreading, gray, fimbriate.

Broth: Slow, moderate growth.

Litmus milk: No change.

Potato: Moderate, gray growth; medium becoming dark.

H_2S not produced.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Decomposing materials.

2. **Kurthia zenkeri** (Hauser) Bergey et al. (*Proteus zenkeri* Hauser, Ueber Faulnissbakterien, 1885; *Bacillus zenkeri* Trevisan, I Genera e la Specie delle Batteriacee, 1889, 17; *Zopfius zenkeri* Wenner and Rettger, Jour. of Bact., *4*, 1919, 334; Bergey et al., Manual, 2nd ed., 1925, 215.)

Rods: 0.65 by 1.6 to 2.3 microns, occurring in pairs and in chains. Motile with peritrichous flagella. Gram-positive.

Gelatin colonies: Feathery, with filaments extending in all directions.

Gelatin stab: Surface growth like colonies. No arborescent growth in stab. No liquefaction.

Agar colonies: Thin, filamentous, spreading, grayish.

Agar slant: Thin, bluish-gray, filamentous.

Broth: Slightly turbid, with gray sediment.

Litmus milk: No change.

Potato: Barely visible, yellowish-gray, glistening.

Indol not formed.

Nitrates not reduced.

H_2S not formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Decomposing materials.

Note: Wenner and Rettger, Jour. Bact., *4*, 1919, 351, consider the two species in this genus to be identical.

Genus XIII. **Listerella Pirie, 1927.**

Short rods, occurring singly and in pairs. Gram-positive. Motile. Grow on solid media with almost transparent growth. Certain carbohydrates are attacked. Strictly aerobic.

The type species is *Listerella monocytogenes* (Murray et al.) Pirie.

1. **Listerella monocytogenes** (Murray et al.) Pirie. (*Bacterium monocytogenes* Murray, Webb and Swann, Jour. Path. and Bact., *39*, 1926, 407–439; *Listerella hepatolytica* Pirie, Publ. So. African Inst. for Med. Res., *3*, 1927, 163–186; *idem.*, 183.)

Small rods, 0.5 by 1.0 to 2.0 microns, with rounded ends, slightly curved in some culture media. Occur singly, in V-shaped or parallel pairs and in short chains. Motile with a single very long terminal flagellum. Gram-positive.

Gelatin: No liquefaction. Growth is confined to the needle track.

Sheep liver extract agar colonies: Circular, smooth, slightly flattened, transparent by transmitted, and milk-white by reflected light. Viscid.

Sheep liver extract agar slant: confluent, flat, transparent, viscid growth.

Peptone agar: Growth is thinner than on liver extract agar.

Peptone broth: Surface film with flocculent sediment.

Litmus milk: Slightly acid, decolorized. No coagulation.

Glycerin-potato: No apparent growth.

Inspissated ox serum; Grows as a very thin, transparent film.

Dorsett's egg medium: Very thin film.

Indol is not formed.

Acid but no gas is formed from dextrose, maltose, lactose, sucrose, xylose, and glycerol.

No action on arabinose, mannitol, dulcitol or inositol.

All cultures give off a penetrating, rather unpleasant acid smell.

Aerobic.

Optimum temperature 37°C.

Thermal death-point 58°–59°C. in 10 minutes.

Habitat: The cause of a generalized infection in rabbits characterized by marked monocytosis and a fatal infection in gerbilles.

TRIBE IX. PASTEURELLEAE CASTELLANI AND CHALMERS, 1919.

Gram-negative rods showing bipolar staining. Non-motile. Parasitic forms with slight fermentative powers.

There is a single genus.

Genus XIV. Pasteurella *Trevisan, 1887.*

Aerobic, facultative. Powers of carbohydrate fermentation slight; no gas produced. Gelatin not liquefied. Parasitic, frequently pathogenic, producing plague in man and hemorrhagic septicemia in the lower animals.

The type species is *Pasteurella avicida* (Gamaleïa) Trevisan.

Key to the species of genus Pasteurella.

I. Pathogenic for domestic and wild animals.
  1. Milk unchanged.
    a. No growth on potato.
      1. *Pasteurella avicida.*
      2. *Pasteurella murcida.*
    aa. Growth on potato yellowish.
      3. *Pasteurella cuniculicida.*
  2. Milk acid.
    a. No growth on potato.
      4. *Pasteurella suilla.*
    aa. Growth on potato grayish.
      5. *Pasteurella bollingeri.*

II. Pathogenic for man and rodents.
  1. No growth in milk.
      6. *Pasteurella tularensis.*
  2. Milk slightly acid.
      7. *Pasteurella pestis.*

1. **Pasteurella avicida** (Gamaleïa) Trevisan. (*Micrococcus cholerae-gallinarum* Zopf, Die Spaltpilze, 1885, 57; *Bacillus cholerae gallinarum* Flügge, Die Microorganismen, 1886, 253; *Bacterium cholerae gallinarum* Schroeter, Kryptogamen Flora von Schlesien, *3*, 1, 1886, 155; *Pasteurella cholerae gallinarum* Trevisan, Rendiconti Reale Instituto Lombardo di Scienze e Lettere, 1887, 94; *Coccobacillus avicidus* Gamaleïa, Cent. f. Bakt., *4*, 1888, 167; Trevisan, I Generi e le Specie delle Batteriacee, 1889, 21; *Pasteurella gallinae* Besson, Practical Bacteriology, London and New York, 1913, 447; *Bacillus avisepticus* Kitt, in Kolle and Wassermann, Handbuch der Pathogenen Mikroorganismen, *6*, 1913, 38.)

Small rods: 0.25 to 0.4 by 0.5 micron, with rounded ends, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Very slight development.

Gelatin stab: Slight surface growth. Translucent, whitish, filiform growth in stab. No liquefaction.

Agar colonies: Transparent, bluish, becoming semi-opaque.

Agar slant: Thin, white, glistening.

Broth: Turbid, with slight grayish pellicle and heavy viscid sediment.

Litmus milk: Reaction unchanged. No coagulation.

Potato: Sometimes shows slight growth.

Indol formed by many cultures.

Nitrates frequently reduced.

Acid in dextrose, levulose, galactose, sucrose and mannitol. No acid in lactose.

Aerobic, facultative.

Optimum temperature 37° to 39°C.

Habitat: The cause of fowl cholera and septicemia in other domestic and wild birds.

2. **Pasteurella muricida** Meyer and Batchelder. (Jour. Infect. Dis., *39*, 1926, 386.)

Rods: 0.2 by 0.3 to 0.7 micron, occurring singly or in short chains. Non-motile. Gram negative.

Gelatin colonies: Small, grayish, entire.

Gelatin stab. No liquefaction. Filiform growth in stab.

Agar colonies: Circular, translucent becoming opaque in center, viscid, entire.

Broth: Slight turbidity with slimy, to flaky, sediment and delicate pellicle.

Bromcresol purple milk: Unchanged.

Potato: No growth.

Indol is formed.

Nitrates are reduced.

Acid in dextrose, levulose and galactose. No action on lactose or sucrose

Aerobic.

Optimum temperature 37°C.

Habitat: Septicemia and focal lesions in white rats resembling plague. Pathogenic for rabbits, guinea pigs, mice, white and gray rats, but not for pigeons and chickens.

3. **Pasteurella cuniculicida** (Flügge) Trevisan. (*Bacillus cuniculicida* Flügge, Die Microorganismen, 1886, 251; Trevisan, I Generi e le Specie delle Batteriacee, 1889, 21; *Bacterium lepisepticum* Ferry and Hoskins, Jour. Lab. and Clin. Med., *5*, 1920, 311.)

Rods: 0.6 to 0.7 by 1.4 to 2.6 microns, occurring singly, occasionally in short chains showing bipolar staining. Non-motile. Gram-negative.

Gelatin colonies: Small, circular, white, finely granular, undulate.

Gelatin stab: Soft, white, surface growth. No liquefaction.

Agar colonies: Whitish, glistening, raised, circular, undulate margin.

Agar slant: Moderate, translucent, whitish, smooth, moist, glistening, undulate.

Broth: Turbid becoming clear, with grayish sediment and pellicle.

Litmus milk: Unchanged or slightly acid.

Potato: Slight whitish-gray to pale yellowish, translucent streak.

Indol is formed.

Nitrates not reduced.

Acid in dextrose and sucrose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Occurs in contagious nasal catarrh in rabbits ("snuffles"). Produces septicemia in rabbits on inoculation. Infectious for chickens and a variety of other animals.

4. **Pasteurella suilla** Trevisan. (Rothlaufstäbchen, Loeffler, Arbeit. a. a. d. k. Gesundheitamt, *1*, 1886, 51; Rothlaufbacillen, Schütz, *ibid.*, p. 74; Bacillus of swine plague, Salmon, U. S. Dept. Agr., Bur. An. Ind., 1886, 87; *Bacillus parvus ovatus* Flügge, Die Microorganismen, 1886, 273; Trevisan, Reale Instituto Lombardo d. sci., e let. Rend., Ser. 2, *20*, 1887, 94; *Bacterium suicida* Migula, in Engler and Prantl's Natürl. Pflanzenfam., *1*, la, 1895, 27; *Bacillus suisepticus* Kruse, in Flügge's Die Mikroorganismen, 1896, 419; *Pasteurella suiseptica* Bergey et al., Manual, 1st ed., 1923, 266.)

Rods: 0.4 to 0.5 by 1.0 to 1.5 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Hazy, bluish-gray, racemose.

Gelatin stab: No surface growth. No liquefaction.

Agar colonies.

Agar slant: Scanty growth, may become slimy.

Broth: Slight turbidity, with grayish sediment.

Litmus milk: Acid. Litmus reduced.

Potato: No growth.

Indol is sometimes formed.

Nitrates not reduced.

Microaerophilic.

Optimum temperature 37°C.

Habitat: The causative agent of swine plague. Pathogenic for mice, rabbits and birds on subcutaneous injection. Produces septicemia in swine on subcutaneous injection.

5. **Pasteurella boviseptica** (Kruse) Holland. (Microparasiten bei eine neue Wild- und Rinderseuche, Bollinger, Über eine neue Wild- und Rinderseuche unsw., München, 1878; *Bacterium bipolare multocidum* Kitt, Sitz., Ges. Morph. u. Physiol. in München, *1*, 1885, 24; *Bacillus septicemia hemorrhagica* Hueppe, Berliner Klin. Wochenschrift, 1886; *Pasteurella bollingeri* Trevisan, I Generi e le Specie delle Batteriacee, 1889, 21; *Bacillus bovisepti-*

cus Kruse, Flügge's Die Mikroorganismen, 1896, 421; *Bacterium multocidum* Lehmann and Neumann, Atlas u. Grundriss d. Bakteriologie, 1899 (Eng. trans. 2nd. ed., 1901, 211); *Bacterium bovisepticum* Migula, System der Bakterien, 1900, 367; Holland, Jour. Bact., *5*, 1920, 224.)

Rods: 0.5 by 0.6 to 1.0 micron, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, circular, glistening, granular, entire.

Gelatin stab: Slight surface growth. No liquefaction.

Agar slant: Grayish-white, slightly raised, undulate.

Broth: Turbid.

Litmus milk: Acid. Litmus reduced.

Potato: Grayish-white, slightly raised.

Small amount of indol formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Causes hemorrhagic septicemia in domestic cattle, hogs and horses. Attacks deer and wild hogs.

6. **Pasteurella tularensis** (McCoy and Chapin) Bergey et al. (*Bacterium tularense* McCoy and Chapin, Jour. of Infect. Dis., *10*, 1910, 61; Hygienic Laboratory Bull. No. 130, 1922.)

Rods: 0.2 by 0.3 to 0.7 micron, occurring singly. Non-motile. Gram-negative.

Growth occurs on media containing egg yolk, on blood agar, dextrose blood agar and dextrose serum agar. The addition of fresh sterile rabbit spleen to the media favors the growth of the organism.

Forms minute viscous colonies.

No growth in milk.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from ground squirrels. Infectious for rabbits, guinea pigs, rats, gray mice and ground squirrels. The cause of "tularemia" in man and transmitted from wild animals to man by biting insects or by contact with infected animals.

7. **Pasteurella pestis** (Lehmann and Neumann) Bergey et al. (Bacille de la peste, Yersin, Annales de l'Institut Pasteur, *8*, 1894, 666; Pest Bacillus, Aoyama, Zeit. f. Hygiene *21*, 1895, 165; *Bacterium pestis* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 194; *Bacillus pestis bubonicae* Kruse, Flügge's, Die Mikroorganismen, 1896, 429; *Bacillus pestis* Migula, System der Bakterien, 1900, 749; Bergey et al., Manual, 1st ed., 1923, 267.)

Rods: 1.0 by 2.0 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Flat, gray, with granular margin.

Gelatin stab: Flat surface growth. Arborescent growth in stab. No liquefaction.

Agar colonies: Grayish-white, translucent, iridescent, undulate.

Agar slant: Grayish, viscid, thin, moist, translucent.

Broth: Turbid, with flocculi in the fluid. Old cultures show pellicle with streamers into the fluid (stalactites).

Litmus milk: Slightly acid. No coagulation.

Potato: Scanty, grayish growth.

Indol not formed.

Nitrates not reduced.

Does not attack lactose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The causative organism of plague in man, rats and ground squirrels. Infectious for mice, guinea pigs and rabbits. Transmitted from rat to rat and from rat to man by the infected rat flea.

TRIBE X. KLEBSIELLEAE TREVISAN, 1887.[1]

Short rods, somewhat plump with rounded ends, mostly occurring singly. Encapsulated. Non-motile. Gram-negative. Ferment a number of carbohydrates with the formation of acid and gas. Encountered principally in the respiratory tract of man. Aerobic, growing well on ordinary culture media.

Genus XV. Klebsiella *Trevisan, 1885.*[2]

The generic characters are those of the tribe.

The type species is *Klebsiella pneumoniae* Trevisan.

Key to the species of genus Klebsiella.

1. Acid and gas in dextrose, lactose and sucrose.
   a. Nitrates reduced to nitrites.
      1. *Klebsiella pneumoniae.*
      2. *Klebsiella granulomatis.*
2. Acid and gas in dextrose and sometimes in lactose.
   a. Nitrates reduced to nitrites.
      3. *Klebsiella rhinoscleromatis.*
      4. *Klebsiella capsulata.*
   aa. Nitrates not reduced.
      5. *Klebsiella ozaenae.*
3. No acid or gas in carbohydrate media.
      6. *Klebsiella cyprinicida.*

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[1] The tribal name *Encapsulateae* and the generic name *Encapsulatus* employed in the first edition of the Manual are invalid because of the prior use of *Klebsielleae* and *Klebsiella.*

[2] The generic name *Encapsulatus* proposed by Castellani and Chalmers is invalid because of the earlier valid name *Klebsiella* proposed by Trevisan.

1. **Klebsiella pneumoniae** (Schroeter) Trevisan. (Pneumoniecoccus, Friedlaender, Virchow's Archive, *87*, 1882, 319; *Bacterium pneumonie crouposae* Zopf, Die Spaltpilze, 3 Aufl., 1885, 66; *Klebsiella crouposa* Trevisan, Atti dell' Accad. fissio-medico-statistica di Milano, Ser. 4, *3*, 1885, 105; *Hyalococcus pneumoniae* Schroeter, Cohn's Kryptogamen Flora von Schlesien, *3*, 1, 1886, 152; *Bacillus pneumoniae* Flügge Die Mikroorganismen, 1886, 204; Trevísan, Rend. d. R. Istit., Lombardo, ser. 2, *20*, 1887, 94; *Klebsiella friedlanderi* Trevísan, I Genera e le Specie delle Batteriacee, 1889, 26; *Bacterium pneumoniae* Migula, System der Bakterien, 1900; *Encapsulatus pneumoniae* Castellani and Chalmers, Manual of Tropical Medicine, 1919, 934; also Bergey et al., Manual, 1st ed., 1923, 238.

Rods: 0.3 to 0.5 by 5.0 microns, with rounded ends, often four to five times as long as broad, occurring singly and in pairs. Encapsulated. Non-motile. Gram-negative.

Gelatin colonies: Dirty-white, smooth, opaque, entire, slightly raised.

Gelatin stab: Dirty-white surface growth. Filiform growth in stab. No liquefaction. Gas bubbles.

Agar colonies: White, shiny, convex, smooth, glistening, entire.

Agar slant: Slimy, white, somewhat translucent, raised.

Broth: Turbid, with thick ring or film.

Litmus milk: Acid; no coagulation.

Potato: Yellowish slimy, raised. Gas is formed.

Indol not formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, lactose and sucrose. No acid or gas in maltose, arabinose, raffinose, inulin, mannitol or dulcitol.

Aerobic, facultative.

Optimum temperature 37°C.

Common name: Pneumobacillus.

Habitat: Associated with pneumonia and other inflammations of the respiratory tract.

2. **Klebsiella granulomatis** (Beaurefaire-Aragao and Vianna) Bergey et al. (*Calymmatobacterium granulomatis* Beaurefaire-Aragao and Vianna, Mem. do Inst. Oswaldo Cruz., Rio de Janeiro *4*, 1912, 211; *Encapsulatus inguinalis* Bergey et al., Manual, 1st ed., 1923, 238; Bergey et al., Manual, 2nd ed., 1925, 264.)

Rods: 0.5 to 1.0 by 0.6 by 5.0 microns (often are coccoid in the tissues) occurring singly, and frequently show one or more metachromatic granules. Encapsulated. Non-motile. Gram-negative.

Gelatin colonies: Small, white, circular, convex, entire.

Gelatin stab: Mucoid surface growth. No liquefaction.

Agar colonies: Grayish-white, translucent, glistening, convex, viscid. Grayish-brown by reflected light.

Agar slant: Grayish-white, mucoid, viscid, semifluid layer.

Broth: Turbid, with gray pellicle and abundant ropy sediment.

Litmus milk: Acid; coagulated.
Potato: Abundant, moist, grayish-brown. The medium is darkened.
Indol not formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, dextrin, inulin, salicin and mannitol.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: In lesions of Granuloma inguinala.

3. **Klebsiella rhinoscleromatis** Trevisan. (Rhinoscleromabacillus, v. Fritsch, Wien. Med. Wochenschr., 1882; Cornil, Progres Medical, 1883; Trevisan, Rend. d. R. Istit. Lombardo, Ser. 2, *20*, 1887, 95.)

Rods, with rounded ends, about 0.8 micron wide, occurring singly and in pairs. Encapsulated. Non-motile. Gram-negative.
Gelatin colonies: Circular, white, convex, entire.
Gelatin stab: White, convex surface growth. No liquefaction.
Agar colonies: White, translucent, smooth, glistening
Agar slant: Moist, white, translucent, spreading.
Broth: Turbid, with tough pellicle.
Litmus milk: Unchanged.
Potato: Yellowish-white, slimy, frequently showing gas formation.
Indol not formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose and sometimes in lactose.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: The cause of rhinoscleroma.

4. **Klebsiella capsulata** (Sternberg) Bergey et al. (Kapselbacillus Pfeiffer, Zeitschr. f. Hyg., *6*, 1889, 145; *Bacillus capsulatus* Sternberg, Manual of Bacteriology, 1893, 431; *Bacterium capsulatum* Migula, System der Bakterien, 1900, 349; *Encapsulatus pfeifferi* Bergey et al., Manual, 1st ed., 1923, 239; Bergey et al., Manual, 2nd ed., 1925, 265.)

Thick rods: 0.8 to 1.0 by 1.0 to 1.5 microns, occurring singly, in pairs and occasionally in short chains. Encapsulated. Non-motile. Gram-negative.
Gelatin colonies: Circular, slightly raised, porcelain-white, glistening.
Gelatin stab: White surface growth. No liquefaction.
Agar colonies: White, raised, homogeneous, entire.
Agar slant: Thick, white, plumose, viscid.
Broth: Turbid, with gray ring and sediment.
Litmus milk: Acid; coagulated. Gas is formed.
Potato: Moist, yellowish-white, viscid.
Indol not formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose and lactose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Associated with catarrhal conditions of mucous membrane of respiratory tract. Pathogenic for mice, guinea pigs and pigeons on subcutaneous or intravenous injection.

5. **Klebsiella ozaenae** (Lehman and Neumann) Bergey et al. (*Bacillus mucosus ozaenae* Abel, Cent. f. Bakt., *13*, 1893, 161; *Bacterium ozaenae* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 204; *Encapsulatus ozenae* Bergey et al., Manual, 1st ed., 1923, 240; Bergey et al., Manual, 2nd ed., 1925, 266.)

Plump rods: 1.25 microns in width and of variable length, occurring singly. Encapsulated. Non-motile. Gram-negative.

Gelatin colonies: Small, white, convex, slimy, translucent.

Gelatin stab: Translucent, slimy surface growth. Filiform growth in stab. No liquefaction.

Agar slant: Slimy, cream-like, spreading.

Broth: Turbid, with gray ring and sediment.

Litmus milk: Acid.

Potato: Creamy, spreading growth.

Indol not formed.

Nitrates not reduced.

Acid and gas in dextrose, levulose, maltose, sucrose, mannitol and sometimes in lactose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Encountered in ozena. Infectious for house and field mice.

6. **Klebsiella cyprinicida** (Plehn) Bergey et al. (*Bacterium cyprinicida* Plehn, Cent. f. Bakt., I Abt., Orig., *35*, 1903–04, 461; Bergey et al., Manual, 2nd ed., 1925, 266.)

Rods: 0.8 by 1.0 micron, occurring singly and in chains. Encapsulated. Non-motile. Gram-negative.

Gelatin colonies: White, glistening, convex, with slight fluorescence around the colony in three or four days.

Gelatin stab: White, convex surface growth. No liquefaction.

Agar slant: White, glistening layer, becoming slimy.

Broth: Turbid, with thick gray pellicle and slimy sediment.

Litmus milk: Slightly alkaline. No coagulation.

Potato: Light yellowish layer, becoming dark brownish. The medium is dark, violet-gray.

Indol not formed. Nitrates not reduced.

No acid in carbohydrate media. Aerobic, facultative.

Optimum temperature 10° to 20°C.

Habitat: The cause of a fatal disease in carp, showing as red spots on the ventral surface.

Also see **Klebsiella parolytica** Wallace, Cahn and Thomas, Jour. Inf. Dis., *53*, 1933, 386.

TRIBE XI. HEMOPHILEAE COMMITTEE S. A. B., 1920.

Minute parasitic forms growing only in the presence of hemoglobin, ascitic fluid or other body fluids, or in the presence of certain growth accessory substances found in sterile, unheated plant tissue (potato). Non-motile. Gram-negative.

Key to genera of tribe **Hemophileae.**

1. Aerobic species.

   Genus XVI. *Hemophilus*, p. 337.

2. Anaerobic species.

   Genus XVII. *Dialister*, p. 341.

Genus XV. **Hemophilus** Winslow et al., *1917.*

Minute rod-shaped cells, sometimes thread forming and pleomorphic. Non-motile. Strict parasites growing best (or only) in the presence of hemoglobin and in general requiring blood serum, ascitic fluid, or certain growth accessory substances. Gram-negative.

The type species is *Hemophilus influenzae* (Lehmann and Neumann) Winslow et al.

Key to the species of genus **Hemophilus.**

1. Affecting the respiratory tract.

   1. *Hemophilus influenzae.*
   2. *Hemophilus hemolyticus.*
   3. *Hemophilus pertussis.*

2 Affecting the conjunctiva.

   4. *Hemophilus conjunctivitidis.*
   5. *Hemophilus lacunatus.*

3. Affecting the genital region.

   6. *Hemophilus ducreyi.*
   7. *Hemophilus canis.*
   8. *Hemophilus melaninogenicus.*

1. **Hemophilus influenzae** (Lehmann and Neumann) Winslow et al. (Influenzabacillus, Pfeiffer, Deutsche Med. Wochenschr., 1892, 28; Zeitschr. f. Hyg., *13*, 1893, 357; *Bacterium influenzae* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 187; *Bacillus infuenzae* Kruse, Flügge's Die Mikroorganismen, 1896, 434; Winslow et al., Jour. Bact., *2*, 1917, 561.)

Very small rods: 0.2 to 0.3 by 0.5 to 2.0 microns, occurring singly and in pairs, occasionally in short chains, and at times long thread forms are seen. Frequently show a marked tendency to bipolar staining. Non-motile. Gram-negative.

Best growth on media containing blood.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Blood agar colonies: Small, circular, transparent, homogeneous, entire.
Blood agar slant: Thin, filiform, transparent.
Blood broth: Slightly turbid. No hemolysis.
Litmus milk, with blood: Some strains render it very slightly alkaline.
Sterilized potato slant: No growth.
Fresh unheated sterile potato added to broth favors development.
Indol is formed by some strains.
Nitrates are reduced to nitrites.
Some strains attack none of the carbohydrates, while other strains attack various carbohydrates, provided a suitable medium is used.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Found in the respiratory tract and was regarded by Pfeiffer and others to be the cause of influenza.

2. **Hemophilus hemolyticus** Bergey et al. (Bacillus X, Pritchett and Stillman, Jour. of Exp. Med., *29*, 1919, 259; Stillman and Bourn, Jour. of Exp. Med., *32*, 1920, 665; Bergey et al., Manual, 1st ed., 1923, 269.)
Some strains are morphologically like *Hemophilus influenzae*, other strains are somewhat larger and stain more heavily and more evenly. Non-motile. Gram-negative.
No growth on ordinary culture media.
Blood agar colonies: Like *Hemophilus influenzae*.
Blood agar slant: Thin, filiform, transparent.
Blood broth: Turbid, showing hemolysis.
Blood milk mixture: Slightly alkaline.
Sterile unheated potato favors development.
Some strains do not attack carbohydrates, other strains ferment various carbohydrates.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Found in upper respiratory tract of man. Non-pathogenic.

3. **Hemophilus pertussis** Holland. (Microbe de coqueluche, Bordet and Gengou, Ann. de l'Institut Pasteur, *20*, 1906, 731; Holland, Jour. Bact., *5*, 1920, 215.)
Short, oval rods: 0.2 to 0.3 by 0.5 to 2.0 microns, occurring singly, sometimes in pairs frequently showing tendency to bipolar staining. Non-motile. Gram-negative.
Gelatin colonies: No growth.
Gelatin stab: No growth.
Blood agar colonies: Small, transparent, entire.
Plain agar slant: (After several generations on artificial media.) Very slight, filiform, translucent.
Broth: Turbid, with heavy, ropy sediment and floating strands.
Litmus milk: Alkaline; decolorized (10 to 20 days).
Potato: Light yellow streak, becoming tan color.

Indol not formed.
Nitrates not reduced.
No action in carbohydrate media.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Believed to be the cause of whooping cough. Serologically two distinct types are distinguished.

4. **Hemophilus conjunctivitidis** Bergey et al. (Koch, Wiener Med. Wochenschrift, *33*, 1883, 1550; Weeks, New York Med. Record, *31*, 1887, 571; Bergey et al., Manual, 1st ed., 1923, 270.)

Small rods: 0.2 to 0.3 by 0.5 to 2.0 microns, with rounded ends, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: No growth.
Gelatin stab: No growth.
Blood agar colonies: Small, transparent, entire.
Broth: No growth.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
No action in carbohydrate media.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: The cause of acute, infectious conjunctivitis.

5. **Hemophilus lacunatus** Holland. (Diplobacille de la conjunctivite subaiguë, Morax, Ann. de l'Institut Pasteur, *10*, 1896, 337; Diplobacillus of chronic conjunctivitis, Axenfeld, Cent. f. Bakt., *21*, 1897, 1; Holland, Jour. Bact., *5*, 1920, 215.)

Short rods: 0.4 to 0.5 by 2.0 microns, occurring singly and in pairs and in short chains. Ends rounded or square in the chains. Non-motile. Gram-negative.
Gelatin colonies: No growth.
Gelatin stab: No growth.
Blood agar colonies: Small, circular, transparent, entire.
Serum agar colonies: Delicate, grayish.
Löffler's blood serum: Slow but definite liquefaction around the colonies.
Ascitic broth: Turbid with slight, grayish sediment.
Blood milk mixture: Doubtful development.
Litmus milk: Unchanged.
Potato: No growth.
Indol is not formed.
Nitrates not reduced.
Various carbohydrates and mannitol are attacked.
Aerobic, facultative.
Optimum temperature 37°C.

Habitat: The cause of subacute infectious conjunctivitis, or "angular conjunctivitis."

6. **Hemophilus ducreyi** Bergey et al. (Ducrey, Cong. internat. de dermatol et syph., Compt. rend., Paris, 1890, 229; Monatshefte f. prakt. Dermatol., *9*, 1889, 387; Riforma med., *5*, 1889, 98; Bergey et al., 1st ed., 1923, 271.)

Small rods: 0.5 by 1.5 to 2.0 microns, with rounded ends, occurrin. singly and in short chains. Non-motile. Gram-negative.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Blood agar colonies: Small, grayish, glistening, showing a slight zone of hemolysis around the colony in three or four days.

Best growth is obtained on clotted rabbit, sheep, or human blood heated to 55°C. for 15 minutes, and in casein digest agar containing blood.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The cause of soft chancre (chancroid).

7. **Hemophilus canis** Rivers. (*Bacillus hemoglobinophilus canis* Friedberger, Cent. f. Bakt., I Abt., Orig., *33*, 1902–03, 401; Rivers, Johns Hopkins Bull., *33*, 1922, 149; Jour. of Bact., *7*, 1922, 579.)

Small rods: 0.2 to 0.3 by 0.5 to 2.0 microns, occurring singly, in pairs and short chains. Non-motile. Gram-negative.

No growth on ordinary culture media.

Blood agar colonies: Small, clear, transparent, entire. Old colonies become opaque.

Blood broth: Turbid.

Blood milk mixture: Doubtful development.

Indol is formed.

Nitrates reduced to nitrites.

Various carbohydrates are attacked, including mannitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Occurs in large numbers in prepucial secretions of dogs.

8. **Hemophilus melaninogenicus** (Oliver and Wherry) Bergey et al. (*Bacterium melaninogenicum* Oliver and Wherry, Jour. Infect. Dis., *28*, 1921, 341; Bergey et al., Manual, 3rd ed., 1930, 314.)

Rods: 0.8 by 1.0 to 3.0 microns. Non-motile. Gram-negative.

Serum gelatin stab: No liquefaction.

Blood agar slant: Confluent, black, dry layer. The blood is disintegrated forming melanin. The medium becomes colorless.

Sodium phosphate broth: Turbid.

Litmus milk: Slow acidification.

Potato: No growth.

Blood serum: Fairly luxuriant, white layer.

Acid formed from dextrose, levulose, lactose, maltose, sucrose and mannitol.

Anaerobic.

Optimum temperature 37°C.

Habitat: Oral cavity and genitalia.

Genus XVII. **Dialister** *Bergey et al., 1923.*

Minute rod-shaped cells, occurring singly, in pairs and short chains. Non-motile. Strict parasites. Growth occurs only under anaerobic conditions in media containing fresh, sterile tissue or ascitic fluid.

1. **Dialister pneumosintes** (Olitsky and Gates) Bergey et al. (*Bacterium pneumosintes* Olitsky and Gates, Jour. of Exp. Med., *33*, 1921, 713; *ibid.*, *35*, 1922, 813.)

Very short rods, 0.15 to 0.3 (0.5 to 1.0, in dextrose broth) micron in length, occurring singly and occasionally in pairs or chains. The ends are rather pointed. Non-motile. Gram-negative.

Blood agar colonies: Small, clear, circular, entire, translucent.

Growth occurs in media containing fresh, sterile rabbit kidney and ascitic fluid.

Dextrose broth in which *Escherichia coli* or *Bacillus mesentericus* (non-spore stage) had grown, favors development.

Old cultures in dextrose media show acid.

Strict anaerobe.

Filter passer.

Optimum temperature 37°C.

Habitat: Occurs in the nasal secretions of influenza patients, in the early hours of the disease.

2. **Dialister granuliformans** (Pavlovic) *comb. nov.* (*Bacterium granuliformans* Pavlovic, Cent. f. Bakt., I Abt., Orig., *112*, 1929, 432.)

Small rod, non-motile. Gram negative.

Gelatin stab:

Agar colonies: Very small, transparent.

Agar slant:

Broth: Turbid.

Litmus milk—No change.

Potato:

Indol is not formed.

Nitrates.

Acid formed in dextrose, sucrose and mannitol.

Passes through Chamberland L_2 filters.

Anaerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from respiratory tract in influenza. Pathogenic for rabbits.

TRIBE XII. BACTERIEAE COMMITTEE S. A. B., 1920.

Gram-negative rods occurring commonly in the intestinal tract of animals. Grow well on artificial media. Many species attack carbohydrates forming acid or acid and gas. Relatively few species liquefy gelatin. When motile, the flagella are generally peritrichous.

Key to the genera of tribe **Bacterieae.**

A. Ferment dextrose with formation of acid or acid and gas.
  1. Acid or acid and gas formed from lactose.
    a. Acetylmethylcarbinol not formed.
    b. Gelatin not liquefied.
      Genus XVIII. *Escherichia*, p. 342.
    aa. Acetylmethylcarbinol is formed.
    b. Gelatin may or may not be liquefied.
      Genus XIX. *Aerobacter*, p. 356.
  2. No acid or gas formed from lactose.
    a. Acid and gas formed from sucrose by some species.
    b. Gelatin liquefied.
      Genus XX. *Proteus*, p. 361.
    aa. No acid or gas in sucrose.
    b. Gelatin not liquefied.
      Genus XXI. *Salmonella*, p. 368.
AA. Ferment dextrose with formation of acid but no gas.
    a. Motile.
      Genus XXII. *Eberthella*, p. 381.
    aa. Non-motile.
      Genus XXIII. *Shigella*, p. 388.
AAA. Do not form acid or gas from carbohydrates.
  1. Grow in media containing basic fuchsin or thionin.
      Genus XXIV. *Brucella*, p. 397.
  2. Do not grow in media containing basic fuchsin or thionin.
      Genus XXV. *Alcaligenes*, p. 399.

Genus XVIII. **Escherichia*** *Castellani and Chalmers, 1919.*

Motile or non-motile rods, commonly occurring in the intestinal canal of normal animals. Attack numerous carbohydrates forming acid and frequently acid and gas. Do not produce acetylmethylcarbinol.

The type species is *Escherichia coli* (Escherich) Castellani and Chalmers.

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* Assistance has been given by Dr. M. W. Yale, N. Y. Agr. Exp. Sta., Geneva, N. Y., in rearranging the keys and in revising the descriptions of species included in the genera *Escherichia* and *Aerobacter*.

Key to the species of genus **Escherichia.**

1. No acid or gas in sucrose.
    A. Gelatin not liquefied.
        a. Motile
        b. Acid and gas in salicin.
        c. Acid and gas in dulcitol.
            1. *Escherichia coli.*
        cc. No acid or gas in dulcitol.
            2. *Escherichia paragruenthali.*
        bb. No action on salicin.
        c. Milk acid; coagulated.
        d. Acid and gas in dulcitol.
            3. *Escherichia formica.*
        dd. No acid or gas in dulcitol.
            4. *Escherichia gruenthali.*
        cc. Milk slightly acid; becoming alkaline.
        d. Nitrates reduced.
            5. *Escherichia vekanda.*
        dd. Nitrates not reduced.
            6. *Escherichia pseudodysenteriae.*
        aa. Non-motile.
        b. Acid in salicin.
            7. *Escherichia anaerogenes.*
        bb. Acid and gas in salicin.
            8. *Escherichia enterica.*
        bbb. No action on salicin.
        c. Nitrates reduced.
            9. *Escherichia vesiculiformans.*
        cc. Nitrates not reduced.
            10. *Escherichia acidilactici.*
    AA. Gelatin liquefied.
        a. Motile.
        b. No action on salicin.
            11. *Escherichia alba.*
2. Acid and gas in sucrose.
    A. Gelatin not liquefied.
        a. Motile.
        b. Acid and gas in salicin.
        c. Acid and gas in dulcitol.
            12. *Escherichia communior.*
        cc. No acid or gas in dulcitol
            13. *Escherichia pseudocoloides.*
        bb. No action on salicin.
        c. Milk acid; coagulated.
            14. *Escherichia anindolica.*
        cc. Milk slightly acid; becoming alkaline.

15. *Escherichia alcalescens.*

aa. Non-motile.

b. Acid and gas in salicin.

16. *Escherichia neapolitana.*

bb. No action on salicin.

c. Milk acid; coagulated.

17. *Escherichia pseudocoscoroba.*

cc. Milk slightly acid; becoming alkaline.

18. *Escherichia galactophilae.*

AA. Gelatin liquefied.

a. Motile.

b. Acid and gas in salicin.

19. *Escherichia leporis.*

bb. No action on salicin.

c. Milk acid; coagulated.

20. *Escherichia gastrica.*

cc. Milk acid; becoming alkaline.

21. *Escherichia plebeia.*

aa. Non-motile.

b. No action on salicin.

22. *Escherichia ellingeri.*

1. **Escherichia coli** (Migula) Castellani and Chalmers. (*Bacterium coli commune* Escherich, Die Darmbakterien des Neugeborenen und Säuglings, 1885; *Bacillus escherichii* Trevisan, I gen. e. le specie d. batter., 1889, 15; *Bacillus coli communis* Sternberg, Manual of Bacteriology, 1893, 439; *Bacillus coli* Migula in Engler and Prantl, Natürlichen Pflanzenfam., *1*, 1a, 1895, 27; *Bacterium coli* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 224; *Bacillus coli verus* Durham, Jour. Exp. Med., *5*, 1900, 371; *Bacillus coli communis verus* Durham, *ibid.*, 353; *Aerobacter coli* Beijerinck, Cent. f. Bakt., II Abt., *6*, 1900, 193; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 941.)

Note: Weldin, Iowa State Jour. Sci., *1*, 1927, 121, considers the following to be synonyms of the above; *Bacillus cavicida* Flügge, Die Mikroorganismen, 1886, 268; *Bacillus C* Booker, Trans. Ninth Internat. Med. Congress, *3*, 598; *Bacillus schafferi* v. Freudenreich, Landw. Jahrb. d. Schweiz. *4*, 1890, 17; *Bacterium cavicida* Migula, System der Bakterien, 1900, 422; *Bacillus mustelae septicus* Matzuschita, Bakteriologisches Diagnostik, 1902; *Bacillus communis* Jackson, Jour. Infec. Dis., *8*, 1911, 241; *Escherichia schafferi* Bergey et al., Manual, 1st ed., 1923, 196; *Escherichia cavicida*, Castellani and Chalmers, Manual of Tropical Medicine, 1919, 942.)

Short rods: 0.5 by 1.0 to 2.0 microns, occurring singly, in pairs and short chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Opaque, moist, grayish-white, entire.

Gelatin stab: Grayish-white, spreading, undulate. No liquefaction.

Agar colonies: White to yellowish-white, entire to undulate, moist, homogeneous, spreading.

Agar slant: White to yellowish-white, moist, glistening, spreading, becoming dirty-brown.

Broth: Turbid, with heavy grayish sediment. No pellicle.

Litmus milk: Rapid acid formation and coagulation; no peptonization.

Potato: Abundant, grayish to yellowish-brown, spreading.

Acid and gas in dextrose, levulose, galactose, arabinose, lactose, maltose, raffinose, dextrin, salicin, mannitol, dulcitol and sorbitol. No acid or gas in adonitol.

Indol is formed.

Nitrates reduced to nitrites.

Fecal odor produced.

Aerobic, facultative.

Optimum temperature 37°C.

Common name, Colon bacillus.

Habitat: Intestinal canal of man and all vertebrates. A "commensal" species. Invades the circulation in agonal stages of diseases. May cause infection of gall bladder, kidney and bladder.

2. **Escherichia paragruenthali** Castellani and Chalmers. (Manual of Tropical Medicine, 1919, 942.)

Note: Weldin, Iowa State Jour. Sci., *1*, 1927, 133, consider this organism to be a synonym of *Escherichia gruenthali*.

Rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish-white, smooth, entire.

Gelatin stab: Grayish-white surface growth. No liquefaction.

Agar colonies: Moist, gray, soft, entire.

Agar slant: Grayish-white, plumose, moist, entire.

Broth: Turbid, with gray sediment.

Litmus milk: Acid; coagulated.

Potato: Abundant, grayish to brownish, smooth.

Indol formed in slight amount.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, arabinose, maltose, lactose, raffinose, salicin, dextrin, glycerol, mannitol, isodulcitol and sorbitol. No acid or gas formed from dulcitol or adonitol.

raffinose, salicin, dextrin, glycerol, mannitol, isodulcitol and sorbitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from the intestinal tract of persons suffering from "food poisoning."

3. **Escherichia formica** (Omelianski) Bergey et al. (*Bacterium formicum* Omelianski, Cent. f. Bakt., II Abt., *11*, 1904, 184; *Achromobacter formicum* Bergey et al., Manual, 1st ed., 1923, 144; Bergey et al., Manual, 2nd ed.,

1925, 220; *Bacterium methylicus* Loew, Cent. f. Bakt., *12*, 1892, 462 is probably synonymous with this organism.

Rods: 0.7 to 0.8 by 2.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: White, transparent, undulate.

Gelatin stab: Slight surface growth. No liquefaction.

Agar colonies: White, homogeneous, with granular center.

Agar slant: White, homogeneous.

Broth: Turbid, with thin, iridescent pellicle.

Litmus milk: Acid; coagulated.

Potato: Yellowish-brown, the medium turning brown.

Indol not formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, galactose, arabinose, lactose, mannitol, and dulcitol, forming CO_2 and H_2 gas, ethyl alcohol, acetic and lactic acid.

Forms one volume CO_2 and two volumes of hydrogen from formic acid.

Cultures give off odor of putrefaction.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Soil.

4. **Escherichia gruenthali** (Morgan) Castellani and Chalmers. (Das gruenthaler Bacterium, Fischer, Zeitschr. f. Hyg., *39*, 1902, 447; *Bacillus gruenthali* Morgan, Brit. Med. Jour. *1*, 1905, 1257; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 942.)

Rods: 0.5 to 0.7 by 1.0 to 1.5 microns, occurring singly. Motile with four to eight peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish-white to white, moist, cream-like, with radiate ridges, granular, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular, soft, moist, smooth, spreading, entire.

Agar slant: Grayish-white, smooth, moist, spreading and entire.

Broth: Turbid with fragile pellicle.

Litmus milk: Slightly acid, coagulated, becoming alkaline. Reduction of litmus.

Potato: Abundant, slimy, yellowish to yellowish-brown streak.

Indol is formed in 7 days.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, arabinose, xylose, maltose, lactose, trehalose, mannitol, sorbitol and isodulcitol. No acid or gas in sucrose, salicin, dulcitol or adonitol. The gas formed in dextrose broth consists of three parts H_2 and one part CO_2.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from persons suffering from poisoning following the ingestion of "liver paste." Frequently found in intestines of man and animals.

5. **Escherichia vekanda** (Castellani) Bergey et al. (*Bacillus vekanda* Castellani, Jour. Trop. Med. and Hyg., *20*, 181; *Bacterium vekanda* Weldin and Levine, Abs. Bact., *7*, 1923, 13; *Enteroides vekanda* Castellani and Chalmers, Manual of Tropical Medicine, 1919, 941; Bergey et al., Manual, 1st ed., 1923, 197.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Circular, convex, smooth, amorphous, entire. Bluish by transmitted light.

Agar slant: Moderate, flat, smooth, glistening, butyrous.

Broth: Turbid, with viscid sediment.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Moderate, dirty-white streak.

Indol not formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, arabinose, xylose, maltose, lactose, trehalose, glycerol, mannitol, adonitol, dulcitol, sorbitol and isodulcitol. No acid or gas in sucrose, raffinose or salicin.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

6. **Escherichia pseudodysenteriae** Bergey et al. (*Bacterium paradysenteriae*, Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 457; Bergey et al., Manual, 1st ed., 1923, 198.)

Rods: 0.5 by 1.0 to 2.0 microns, occurring singly, in pairs and in short chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish, translucent, finely granular, spreading.

Gelatin stab: Grayish, spreading. No liquefaction.

Agar colonies: Circular, gray, translucent, finely granular, entire.

Agar slant: White, glistening streak.

Broth: Turbid, with heavy grayish sediment.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Luxuriant, yellowish-brown to brown.

Indol is sometimes formed.

Nitrates not reduced.

Acid and gas in dextrose and lactose.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal of normal persons and dysentery patients. Kills mice, guinea pigs and rabbits on subcutaneous inoculation.

7. **Escherichia anaerogenes** Bergey et al. (*Bacterium coli anaerogenes* Lembke, Arch. f. Hyg., *26*, 1896, 299; Bergey et al., Manual, 3rd ed., 1930, 321.)

Rods: Non-motile. Gram-negative.
Gelatin colonies: Like *Escherichia coli.*
Gelatin stab: Like *Escherichia coli.*
Agar colonies: Like *Escherichia coli.*
Agar slant: Like *Escherichia coli.*
Broth: Like *Escherichia coli.*
Litmus milk: Like *Escherichia coli.*
Potato: Like *Escherichia coli.*
Indol formed.
Nitrates reduced.
Acid in dextrose; acid and gas in lactose.
Aerobic, facultative.
Optimum temperature 33°C.
Habitat: Normal intestines.

8. **Escherichia enterica** (Castellani) Weldin. (*Bacillus coli immobilis* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 339; *Bacillus coli immobilis* Chester, Del. Agr. Sta., 9th An. Rept., 1897, 128; *Enteroides entericus* Castellani, Jour. Hyg., *7*, 1907; *Bacillus schafferi* MacConkey, Jour. of Hyg., *9*, 1909, 86; *Bacillus entericus* Castellani and Chalmers, Manual of Tropical Medicine, 1910, 990; *Escherichia schafferi* Castellani and Chalmers, ibid., 1919, 941; *Bacillus coli* var. *immobilis* Winslow et al., Jour. Bact. *4*, 1919, 429; *Bacterium schafferi* Weldin and Levine, Abst. of Bact., *7*, 1923, 13; not *Bacillus entericus*, Ford, Studies from Royal Victoria Hospital, Montreal, 1903; not *Eberthella enterica* Bergey et al., Manual of Determinative Bacteriology, 1923, 223.)

Rods: 0.5 by 1.0 to 2.0 microns, occurring singly and in pairs. Non-motile. Gram-negative.
Gelatin colonies: Grayish-white, moist, entire.
Gelatin stab: No liquefaction.
Agar colonies: Moist, grayish-white, entire.
Agar slant: Grayish-white, plumose streak.
Broth: Turbid.
Litmus milk: Acid; coagulated.
Potato.
Indol formed in slight amount.
Nitrates.
Acid and gas in dextrose, maltose, lactose, salicin, mannitol and dulcitol. No action on sucrose, dextrin or adonitol.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal tract of man and animals.

9. **Escherichia vesiculiformans** (Henrici) Bergey et al. (*Bacillus vesiculiformans* Henrici, Arbeiten a. d. Bakt. Inst. d. techn. Hochschule zu Karlsruhe, 1, 1894, 25; Bergey et al., Manual, 2nd ed., 1925, 222.)

Short rods: 0.8 by 1.2 to 1.5 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Circular, dirty-white, glistening, slimy.

Gelatin stab: No liquefaction

Gas is formed.

Agar colonies: Gray, entire to lobate, small.

Agar slant: Gray, plumose, smooth, thick, slimy, spreading.

Broth: Turbid. With gray, slimy sediment.

Litmus milk: Acid; coagulated.

Potato: Dirty-white smooth.

Indol is formed.

Nitrates reduced to nitrites.

Acid and gas formed in dextrose and lactose. No acid or gas in sucrose, salicin, adonitol or dulcitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from cheese. Also common in intestinal tract.

10. **Escherichia acidilactici** (Zopf) Bergey et al. (Milchsaurebacterium Hueppe, Mit. d. kais. Gesund., *2*, 1884, 340; *Bacillus acidi lactici* Zopf, Die Spaltpilze, 1885, 87; (not *Bacterium acidi lactici* Zopf, Die Spaltpilze, 1884, 60); *Bacillus acidi lactici I* and *II* Grotenfelt, Fortschr. d. Med., *7*, 1889, 121; (Possibly also *Bacterium acidi lactici I* and *II* Grotenfelt, *ibid.*, 123) *Bacterium acidi lactici* Migula, in Engler and Prantl's Natürlichen Pfanzenfamilien, *1*, la, 1895, 25; (Not *Bacterium acidi lactici* Kruse, in Flügge's Die Microorganismen, 1896, 357; Not *Bacterium B* Peters, Bot. Zeitung, *47*, 1889, 422); Possibly *Bacterium grotenfeldtii* Migula, System der Bakterien, 1900, 408, a synonym of *Bacterium acidi lactici I* Grotenfelt; Possibly *Bacillus lacticus* Macé, Traité pratique de bactériologie, 1913, 452; (Not *Bacillus lacticus* Kruse, in Flügge's Die Mikroorganismen, 1896, 356) *Bacterium duodenale* Ford, Studies from Victoria Hospital, Montreal, *1*, 1903, 17 (according to Perkins, Jour. Infec. Dis., *37*, 1925, 247); *Encapsulatus acidi lactici* Castellani and Chalmers, Manual of Tropical Medicine, 1919, 934; (*Encapsulata*) *Bacillus duodenale* Perkins, Jour. Infec. Dis., *37*, 1925, 247; Bergey et al., Manual, 1st ed., 1923, 199.)*

Rods: 0.3 to 0.4 by 1.0 to 1.4 microns, occurring mostly in pairs and in short chains. Non-motile. Gram-negative.

Gelatin colonies: Small, white, glistening, butyrous surface growth. No liquefaction.

Agar slants: White to yellowish, moist, butyrous.

Broth: Turbid.

Litmus milk: Acid and coagulation with gas formation.

Potato: Yellowish-brown streak.

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*List of Synonyms from Breed, in Jordan and Falk, *The Newer Knowledge*, etc., 1928.

Indol is produced.

Nitrates are reduced.

Acid and gas in dextrose, levulose, galactose, arabinose, maltose, lactose, raffinose, dextrin, mannitol, sorbitol and adonitol. No acid or gas in sucrose, salicin or dulcitol.

Odor not characteristic.

Alcohol formed in milk.

Aerobic, facultative.

Best growth at 30°C. Grows well at 37°C.

Habitat: Milk and cheese. Intestinal canal.

11. **Escherichia alba** Schirre (Trans. Royal Soc. of So. Africa, *17*, 1928, *43*.)

Rods: 0.5 by 1.5 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Circular, white, entire. Odor of decomposing shellfish.

Agar slant: Filiform, white, smooth, glistening.

Broth: Turbid.

Litmus milk: Acidified.

Potato: Moist, grayish streak.

Indol is formed.

Nitrates not reduced.

Acid and gas from dextrose, levulose, galactose, lactose, maltose, arabinose, xylose, mannitol and isodulcitol. No acid or gas from sucrose, dextrin, salicin, inulin, dulcitol, sorbitol, adonitol or inositol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Associated with wound infection in frogs.

12. **Escherichia communior** (Jackson) Bergey et al. (*Bacillus coli communior* Durham, Jour. of Exp. Med., *5*, 1900, 353; *Bacterium communior* Jackson, Jour. Infec. Dis., 8, 1911, 241; Bergey et al., Manual, 1st ed., 1923, 200.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, grayish, smooth, glistening, contoured, entire.

Gelatin stab: Gray surface growth with echinulate growth in stab.

Agar colonies: Circular, convex, smooth, amorphous, entire, bluish by transmitted light.

Agar slant: Gray, plumose, lobate, smooth, glistening.

Broth: Turbid, with grayish sediment.

Litmus milk: Acid; coagulated.

Potato: Dirty white, smooth, glistening.

Indol is formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, raffinose, dextrin, salicin, trehalose, glycerol, mannitol, dulcitol, isodulcitol and sorbitol. No acid or gas in adonitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal of normal animals.

Note: Yale, Cornell Vet., *23*, 1933, 306 does not consider *Escherichia astheniae* (Dawson) Bergey et al. (Manual 1st. ed., 1923, 205) a separate species but regards it as a synonym either of *Escherichia coli* or of *Escherichia communior*.

13. **Escherichia pseudocoloides** Castellani and Chalmers (Manual of Tropical Medicine, 1919, 942.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Gray, entire, smooth, glistening.

Agar slant: Gray, smooth, plumose.

Broth: Turbid, with slight grayish pellicle.

Litmus milk: Acid; coagulated.

Potato: Dirty-white, smooth, glistening.

Indol is formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, raffinose, dextrin, salicin, glycerol, mannitol, isodulcitol and adonitol. No acid or gas in ducitol or inositol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal of man.

14. **Escherichia anindolica** Bergey et al. (*Bacterium coli anindolicum* Lembke, Arch. f. Hyg., *26*, 1896, 299; Bergey et al., Manual, 3rd ed., 1930, 325.)

Rods: Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Like *Escherichia communior*.

Gelatin stab: Like *Escherichia communior*.

Agar colonies: Like *Escherichia communior*.

Agar slant: Like *Escherichia communior*.

Broth: Like *Escherichia communior*.

Litmus milk: Like *Escherichia communior*.

Potato: Like *Escherichia communior*.

Indol is not formed.

Nitrates reduced.

Acid and gas in dextrose, lactose and sucrose.

Aerobic, facultative.

Optimum temperature 37°C.
Habitat: Normal intestines.

15. **Escherichia alcalescens** (Ford) Bergey et al. (*Bacterium alcalescens* Ford, Jour. Med. Research, *1*, 1901, 211; Studies from the Royal Victoria Hospital, Montreal, *1*, Pathology II, 1903; Bergey et al, Manual, 1st ed., 1923, 201.)

Rods: 0.5 by 1.0 to 2.0 microns, occurring singly and occasionally in long chains. Motile with peritrichous flagella. Gram-negative.
Gelatin colonies: White with opaque center, spreading.
Gelatin stab: No liquefaction.
Agar colonies: White, opaque, spreading, translucent.
Agar streak: White, translucent, spreading.
Broth: Turbid, with whitish sediment. No pellicle.
Litmus milk: Acid, becoming alkaline. No coagulation.
Potato: Scanty, yellowish-white to dirty-brown streak.
Indol is rarely formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose, lactose, and sucrose. No action on salicin.
Slight fecal odor produced.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

16. **Escherichia neapolitana** (Emmerich) Bergey et al. (*Bacterium neapolitanum* Emmerich, Deutsche med. Wochenschr., 1885; Bergey et al., Manual, 1st ed., 1923, 204.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Non-motile. Gram-negative.
Gelatin stab: No liquefaction.
Agar colonies.
Agar slant: Gray, plumose, smooth, glistening.
Broth: Turbid, with gray sediment.
Litmus milk: Acid; coagulated.
Potato: Dirty white, smooth, glistening.
Indol is formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, dextrin, salicin, raffinose, glycerol, dulcitol and sorbitol. No acid or gas in adonitol.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal tract of man.

17. **Escherichia pseudocoscorobae** Castellani and Chalmers (Manual of Tropical Medicine, 1919, 942.)

Rods: 1.0 by 1.5 to 2.0 microns, occurring singly and showing deeply stained poles and poorly stained center. Non-motile. Gram-negative.

Gelatin colonies: Circular, whitish, raised, opaque.

Gelatin stab: Thin, whitish growth along stab. Raised, white, opaque surface growth. No liquefaction.

Agar slant: Whitish streak, slightly contoured with opaque center and transparent margin. Translucent.

Broth: Turbid, with whitish pellicle and sediment.

Litmus milk: Acid; coagulation.

Potato: Viscid, grayish-white streak.

Indol is formed.

Nitrates.

Forms 40 per cent gas in dextrose, consisting of three parts H_2 and one part CO_2.

Acid and gas in dextrose, maltose, lactose, sucrose, raffinose, dextrin, mannitol and sorbitol. No acid or gas in salicin, dulcitol or adonitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Cause of fatal disease in swans (*Coscoroba candida*) in the zoological gardens at Antwerp, Belgium. Also isolated from sewage.

18. **Escherichia galactophila** (Ford) Bergey et al. (*Bacterium galactophilum* Ford, Jour. Med. Res., *1*, 1901, 211; Bergey et al., Manual, 1st ed., 1923, 202.)

Rods: 0.75 by 1.5 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Irregular, skein-like, white, spreading.

Gelatin stab: Abundant surface growth. No liquefaction.

Agar colonies: Dull, white, circular, moist, entire.

Agar slant: Raised, white, viscid, echinulate.

Broth: Turbid, with pellicle and abundant, white sediment.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Abundant, dull-white growth.

Indol is not formed.

Nitrates reduced to nitrites.

No action on dextrose. Acid and gas in lactose and sucrose.

No characteristic odor formed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

19. **Escherichia leporis** (Chester) Bergey et al. (*Bacillus leporis lethalis* Sternberg, Manual of Bacteriology, 1893, 453; *Bacillus leporis* Chester, Manual, 1901, 243; *Eberthella leporis* Bergey et al., Manual, 1st ed., 1923, 229; Bergey et al., Manual, 2nd ed., 1925, 221.)

Rods: 0.5 by 4.0 to 6.0 microns, occurring singly. Motile, with peritrichous flagella. Gram-negative.

Gelatin colonies: Transparent, spreading, with "broken glass" appearance.

Gelatin stab: Rapid, stratiform liquefaction.

Agar colonies: Circular, grayish, slightly spreading, with serrate margin.

Agar slant: Abundant, white, glistening, becoming brown.

Broth: Turbid.

Litmus milk: Acid with coagulation.

Potato: Luxuriant, yellowish-brown.

Indol is formed.

Nitrates reduced to nitrites.

Acid and gas formed in dextrose, lactose and sucrose.

Odor is sometimes fecal in character.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

20. **Escherichia gastrica** (Ford) Bergey et al. (*Bacillus gastricus* Ford, Studies from The Royal Victoria Hospital Montreal, *1* (Path. II), 1903, 58; Bergey et al., Manual, 1st ed., 1923, 203.)

Rods: 0.5 by 2.0 to 3.0 microns, occurring singly, rarely in short chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Variable in size; grayish-white, with dark center, slightly spreading.

Gelatin stab: Rapid stratiform liquefaction.

Agar colonies: Thick, circular, yellowish-white, opaque, entire.

Agar slant: Abundant, yellowish-white, moist.

Broth: Turbid.

Litmus milk: Acid with coagulation.

Potato: Luxuriant, moist, brownish to brownish-red.

Indol usually produced.

Nitrates reduced to nitrites.

Gas in dextrose, lactose and sucrose.

Fecal odor produced.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

21. **Escherichia plebeia** (Ford) Bergey et al. (*Bacillus plebeius* Ford, Studies from The Royal Victoria Hospital, Montreal, *1* (Path. II), 1903, 41; Bergey et al., Manual, 1st ed., 1923, 203.)

Rods: 0.5 by 1.5 to 3.0 microns, occurring singly, in pairs and long chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: White with darker center, spreading.

Gelatin stab: Rapid, stratiform liquefaction.

Agar colonies: Opaque with white center, spreading. Margin translucent with radiating threads. May be bizarre in shape.

Agar slant: Abundant, white, glistening, spreading.
Broth: Markedly turbid, with delicate pellicle.
Litmus milk: Acid, becoming deeply alkaline. Peptonization.
Potato: Abundant, yellowish, white or creamy-white growth, turning brown to red.
Indol is rarely formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose, lactose and sucrose.
Odor of putrefaction.
Blood serum peptonized.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

22. **Escherichia ellingeri** (Metalnikov and Chorine) Bergey et al. (*Coccobacillus ellingeri* Metalnikov and Chorine, Ann. de l'Institut Pasteur, *42*, 1928, 1635; Bergey et al., Manual, 3rd ed., 1930, 330.)
Rods: 1.0 to 4.0 microns in length, ovoid to short rod forms, occurring singly and in pairs. Non-motile. Gram-negative.
Gelatin stab: Liquefied.
Agar colonies: Small, circular, cream colored center with white border. The medium becomes brownish. Characteristic odor.
Agar slant.
Blood agar: Slow hemolysis.
Broth: Turbid becoming brownish, with abundant sediment.
Litmus milk: Acid, coagulated, decolorized.
Potato: Abundant, yellow streak.
Indol is not formed.
Nitrates reduced to nitrites.
Blood serum liquefied.
H_2S is formed in agar containing lead subacetate.
Acid and gas in dextrose, levulose, galactose, lactose, sucrose, maltose, glycerol and mannitol.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Causes fatal infection in insects, as *Pyrausta nubialis* Hübn, and *Galleria mellonella* L.

Note: Werkman and Gillen, Jour. of Bact., *23*, 1932, 167, have proposed the name **Citrobacter** for a new genus to include forms intermediate between the Genus *Escherichia* and the Genus *Aerobacter*. Seven species are proposed for the genus as follows: *Citrobacter freundii*, *Citrobacter album*, *Citrobacter glycologenes*, *Citrobacter intermedium*, *Citrobacter decolorans*, *Citrobacter diversum* and *Citrobacter anindolicum*.

Genus XIX. Aerobacter *Beijerinck, 1900.*

Motile or non-motile rods, commonly occurring in the intestinal canal of normal animals. Produce acetylmethylcarbinol.

The type species is *Aerobacter aerogenes* (Kruse) Beijerinck.

Key to the species of genus Aerobacter.

A. Non-motile.
 1. Acid and gas formed in sucrose.
  a. No acid or gas in dulcitol.
   1. *Aerobacter aerogenes.*
  aa. Acid and gas in dulcitol.
   2. *Aerobacter oxytocum.*
 2. No acid or gas in sucrose.
   3. *Aerobacter chinense.*

AA. Motile.
 1. Acid and gas formed in sucrose.
  a. Gelatin liquefied.
  b. Gas formed at 37°C.
   4. *Aerobacter cloacae.*
  bb. Gas not formed at 37°C.
   5. *Aerobacter liquefaciens.*
  aa. Gelatin not liquefied.
   6. *Aerobacter hibernicum.*
 2. No acid or gas in sucrose.
   7. *Aerobacter levans.*

1. **Aerobacter aerogenes** (Kruse) Beijerinck. Synonyms: (See Breed in Jordan and Falk, The Newer Knowledge, etc., 1928, 390.) (*Bacterium lactis aerogenes* Escherich, Fortschr. d. Med., *3*, 1885, 515; *Bacterium lactis* Baginsky, Ztschr. f. phys. Chem., *12*, 1888, 437; *Bacterium aceticum* Baginsky, *ibid.*; *Bacillus lactantium* Trevisan, I gen. e le spec. delle batteriacae, 1889, 15; *Bacillus lactis aerogenes* Sternberg, Manual of Bacteriology, 1893, 447; *Bacillus aerogenes* Kruse, in Flugge's Die Mikroörganismen, 1896, 340 (Not *Bacillus aerogenes* Miller, Deutsche med. Wchnschr., *12*, 1886, 119); *Bacterium aerogenes* Chester, Del. Agr. Exp. Sta. 9th Ann. Rept., 1897, 53 (Not *Bacterium aerogenes* Miller, Deutsche med. Wchnschr., 12, 1886, 119); Beijerinck, Arch. néerl. d. sc. exact. et nat., *4*, 1900, 1; *Encapsulatus lactis aerogenes* Castellani and Chalmers, Manual Tropical Med., 1919, 934; [*Encapsulata*] *Bacillus aerogenes* Perkins, Jour. Inf. Dis., *37*, 1925, 254.)

Rods: 0.5 to 0.8 by 1.0 to 2.0 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Thick, porcelain-white, opaque, moist, smooth, entire.

Gelatin stab: Thick, spreading, white, opaque surface growth. No liquefaction.

Agar colonies: Thick, white, raised, moist, smooth, entire.

Agar slant: Abundant, thick, white, moist, glistening, spreading.

Broth: Turbid, with pellicle and an abundant sediment.

Litmus milk: Acid, with coagulation. No peptonization.

Potato: Thick, yellowish-white to yellowish-brown, spreading, with nodular outgrowths over the surface.

Indol not formed.

Nitrates reduced to nitrites

Produces acetylmethylcarbinol.

Acid and gas in dextrose, levulose, galactose, arabinose, lactose, maltose, sucrose, raffinose, dextrin, salicin, glycerol, mannitol, sorbitol, inositol and adonitol. Produces twice as much CO_2 gas as H_2 gas.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal of man and animals. Widely distributed in nature.

2. **Aerobacter oxytocum** (Migula) Bergey et al. (*Bacillus oxytocus perniciosus* Flügge, Die Mikroorganismen, 1886, 268; *Bacterium oxytocum* Migula, System der Bakterien, 1900, 394; *Escherichia oxytocus* Castellani and Chalmers, Manual of Tropical Medicine, 1919, Bergey et al., Manual, 1st ed., 1923, 206.)

Short rods, with rounded ends, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Grayish-white, circular, contoured.

Gelatin stab: Spreading, grayish-white, with greenish shimmer. No liquefaction.

Agar colonies: Grayish-white, smooth, glistening, undulate.

Agar slant: Grayish-white, smooth, homogeneous, undulate.

Broth: Turbid, with grayish sediment.

Litmus milk: Acid, with coagulation.

Potato: Dirty-white, smooth, moist.

Indol is produced.

Nitrates reduced to nitrites.

Acetylmethylcarbinol formed.

Acid and gas in dextrose, levulose, galactose, arabinose, lactose, sucrose, raffinose, salicin, dextrin, inulin, glycerol, mannitol, dulcitol, isodulcitol, sorbitol and adonitol.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Found in dairy products, soil and intestinal tract.

3. **Aerobacter chinense** (Chester) Bergey et al. (*Bacillus capsulatus chinensis* Hamilton, Cent. f. Bakt., II Abt., *4*, 1898, 230; *Bacterium chinense* Chester, Manual of Determinative Bacteriology, 1901, 129; Bergey et al., 1st ed., 1923, 207.)

Rods: 0.6 by 4.0 to 8.0 microns. Non-motile. Gram negative.

Gelatin colonies: Small, white, convex, glistening.

Gelatin stab: No liquefaction.

Agar colonies: White, slimy, glistening, entire.
Agar slant: Thick, slimy, spreading.
Broth: Turbid, with delicate, gray pellicle and flocculent sediment.
Litmus milk: Acid; coagulated. Cheesy odor.
Potato: Thick, creamy layer. Odor of trimethylamine and ammonia.
Indol not formed.
Acid and gas in dextrose, maltose, lactose and glycerol. No acid or gas in sucrose.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from India ink. Pathogenic for white mice and guinea pigs.

4. **Aerobacter cloacae** (Jordan) Bergey et al. (*Bacillus cloacae* Jordan, Rept. Mass. State Bd. of Health, Part II, 1890, 836; Bergey et al., Manual, 1st ed., 1923, 207.)
Rods: 0.5 to 1.0 by 1.0 to 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies: Thin, circular, bluish, translucent.
Gelatin stab: Slow, stratiform liquefaction.
Agar colonies: Circular, thick, opaque with white center, entire.
Agar slant: Porcelain-white, smooth, glistening, spreading.
Broth: Turbid, with thin pellicle.
Litmus milk: Slow acid formation with coagulation. Slow peptonization.
Potato: Growth yellowish, moist, glistening.
Indol may or may not be formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose, levulose, galactose, arabinose, xylose, lactose, maltose, sucrose, raffinose, dextrin, salicin, glycerol, mannitol, sorbitol and trehalose. Inulin, amylum, dulcitol and isodulcitol generally not attacked.
Acetylmethylcarbinol formed.
Fecal odor formed.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

5. **Aerobacter liquefaciens** Grimes and Hennerty. (Sci. Proc. Royal Dublin Society, 20 (N. S.) 1931, 93).
Rods: 0.75 to 1.0 by 1.0 to 2.0 microns. Motile possessing peritrichous flagella. Gram negative.
Gelatin colonies: Two days. Punctiform colonies, which liquefied gelatin. Liquefaction occurred in circular form round the colony itself presenting the customary concave appearance.
Gelatin stab: Three days—filiform growth, with slight liquefaction. Seven days—ten per cent funnel form liquefaction. Twenty-one days—40 per cent liquefaction.
Agar colonies: Five days—surface colonies—good rapid growth, circular, greyish, smooth, glistening, moist, slimy, opaque, convex and entire.

Agar slant: Two days—abundant growth, whitish grey, raised, spreading glistening, with a somewhat slimy appearance, opaque, smooth.

"Levine media": Good growth, typical of the *Aerobacter* group.

Broth: Ten days—good growth, turbid.

Dunham's solution: Ten days—good growth; marked turbidity. Very slight filamentous deposit at the bottom of test tube. Change of pH from 7.0 to 8.2.

Litmus milk: Acid, coagulation, gas.

Plain milk: Acid, coagulation, gas. Acidity after 5 days, 0.46 per cent, and after seven days 0.50 per cent.

Potato: Ten days, abundant growth, pinkish brown, raised, spreading, smooth, glistening, moist, slimy, opaque.

Indol is not formed.

Nitrates are reduced.

Acid and gas in sucrose, lactose, maltose, dextrose, levulose, galactose, arabinose, raffinose, crystal violet lactose, dextrin, salicin, mannitol, sorbitol, inositol. Slight acid but no gas in glycerine and inulin. Neither acid nor gas in dulcitol nor adonitol.

Diastatic action negative.

Methyl red test negative.

Acetylmethylcarbinol produced.

Uric acid medium: Two days—very turbid. Medium changed from pH 6.6 to pH 5.9.

Citrate medium: Two days—marked turbidity. Medium changed from pH 6.6 to pH 7.2.

Aerobic, facultative.

Optimum temperature 25°C. Thermal death point 70°C.

Growth scanty at 37°C. No gas produced at 37°C.

Cultural and physiological characters obtained at 21°C.

Habitat: Isolated from butter and considered to be soil types introduced through water used in washing the butter.

6. **Aerobacter hibernicum** Grimes and Hennerty. (Scientific Proceedings of the Royal Dublin Society, 20, (N. S.) 1931, 92).

Rods: 0.75 to 0.1 by 1.0 to 2.0 microns. Motile possessing peritrichous flagella. Gram negative.

Gelatin colonies: Two days—Punctiform colonies which do not liquefy gelatin.

Gelatin stab: Filiform growth along line of stab, grayish surface growth around point of inoculation. No liquefaction in five weeks.

Agar colonies: Five days—surface colonies—good rapid growth, circular, grayish, smooth, glistening, moist, slimy, opaque, convex, and entire.

Agar slant: Two days—abundant, whitish-gray, raised, smooth, glistening, opaque, slimy. Edge rather definite. "Levine media." Two days—abundant growth typical of the *Aerobacter* group.

Broth: Ten days—good growth, turbid.

Dunham's solution: Ten days—good growth—very turbid.

Change of pH from 7.0 to 8.2.

Litmus milk: Acid, gas, coagulation and ropiness.

Plain milk: Acid, gas, coagulation and ropiness.

Acidity after 4 days. 0.52 per cent; after 7 days 0.34 per cent.

Potato: Ten days—abundant growth, dirty gray to pinkish brown, raised, spreading, smooth, glistening, moist, slimy, opaque.

Indol is not formed.

Nitrates are reduced.

Acid and gas in sucrose, lactose, maltose, dextrose, levulose, galactose, arabinose, raffinose, crystal violet lactose, dextrin, salicin, mannitol, sorbitol and glycerol. Neither acid nor gas in inulin, dulcitol, adonitol. Inositol may or may not be fermented.

Diastatic acid negative.

Methyl red test is negative.

Acetyl-methyl-carbinol is produced.

Uric acid medium: Two days—very turbid. Medium changed from pH 6.8 to pH 6.0.

Citrate medium: Two days—turbid. Medium changed from pH 6.6 to pH 7.0.

Aerobic, facultative.

Optimum temperature 25°C. Thermal death point 66°C.

No gas produced at 37°C.

Cultural and physiological characters obtained at 21°C.

Habitat: Isolated from butter and considered to be soil types introduced through water used in washing the butter.

7. **Aerobacter levans** (Wolffin) Bergey et al. (*Bacterium levans* Wolffin, Inaug. Diss., Wurzburg, 1894; Hollinger, Cent. f. Bakt., II Abt., *9*, 1902, 305; Bergey et al., Manual, 1st ed., 1923, 208.)

Rods: 0.6 by 1.8 microns, occurring singly and in pairs. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, flat, whitish to bluish, ridged, entire.

Gelatin stab: Slow liquefaction.

Agar slant: Bluish-white, smooth, glistening, undulate.

Broth: Turbid.

Litmus milk: Acid, with coagulation.

Potato: Abundant, dirty-white growth.

Acid and gas in dextrose, levulose, galactose, arabinose, lactose, raffinose, dextrin, inulin, salicin, mannitol and sorbitol. The gas in dextrose consists in one part H_2 and three parts CO_2. No acid or gas in sucrose, dulcitol, adonitol or inositol.

Indol formation is doubtful.

Nitrates reduced to nitrites.

Acetyl-methyl-carbinol formed.

Ferments flour.

Aerobic, facultative.

Optimum temperature 36°C.

Habitat: Isolated from fermenting dough. Found in soil and occasionally in alimentary tract.

Genus XIX. **Proteus** *Hauser, 1885.*

Highly pleomorphic rods. Filamentous and curved rods are common as well as involution forms. Gram-negative. Generally actively motile, possessing peritrichous flagella. Produce characteristic amoeboid colonies on moist media and decompose proteins. Ferment dextrose and generally sucrose but not lactose. Do not usually produce acetylmethylcarbinol.

The type species is *Proteus vulgaris* Hauser.

Key to the species of genus **Proteus.**

1. Acid and gas in sucrose.
    - A. Gelatin liquefied.
        - a. Motile.
        - b. No action on mannitol.
        - c. Acid and gas in maltose.
            - 1. *Proteus vulgaris.*
        - cc. No action on maltose.
            - 2. *Proteus mirabilis.*
            - 3. *Proteus iliacus.*
        - bb. Acid but no gas in mannitol.
        - c. Acid but no gas in maltose.
            - 4. *Proteus noctuarum.*
        - bbb. Acid and gas in mannitol.
        - c. Acid and gas in maltose.
            - 5. *Proteus hydrophilus.*
            - 6. *Proteus ichthyosmius.*
            - 7. *Proteus bombycis.*
    - AA. Gelatin not liquefied.
        - a. Non-motile.
        - b. Acid and gas in mannitol.
        - c. Acid and gas in maltose.
            - 8. *Proteus asiaticus.*
2. Acid and only a small amount of gas in sucrose.
    - 9. *Proteus sphingidis.*
3. No action on sucrose.
    - A. Gelatin liquefied.
        - a. Motile.
        - b. No action on mannitol.
        - c. Indol not formed.
            - 10. *Proteus americanus.*
        - cc. Indol is formed.
            - 11. *Proteus ammoniae.*

AA. Gelatin not liquefied.
a. Motile.
b. Acid and gas in mannitol.
c. No action on salicin.
12. *Proteus valeriei.*
cc. Acid and gas in salicin.
13. *Proteus pseudovaleriei.*

1. **Proteus vulgaris** Hauser. (Sitz.- ber. d. phys.- mediz. Sozietät zu Erlangen, 1885, 156; *Bacillus proteus* Trevisan, I Generi e le Specie delle Batteriacee, 1889, 17; *Bacterium vulgare* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 243; *Bacillus proteus vulgaris* Kruse, in Flügge, Die Mikroorganismen, 1896, 272; *Bacillus vulgaris* Migula, System der Bakterien, 1900, 707; *Bacterium proteus anindologenes* van Loghem, Ann. d. l'Inst. Pasteur, *32*, 1918, 295.)

Rods: 0.5 to 1.0 by 1.0 to 3.0 microns, occurring singly, in pairs and frequently in long chains. Actively motile, with peritrichous flagella. Gram-negative.

Gelatin colonies: Irregular, spreading, rapidly liquefying.

Gelatin stab: Rapid, stratiform liquefaction.

Agar colonies: Opaque, gray, spreading.

Agar slant: Thin, bluish-gray, spreading over entire surface.

Broth: Marked turbidity, usually with a thin pellicle.

Litmus milk: Slightly acid, becoming markedly alkaline. Quick peptonization.

Potato: Abundant, creamy to yellowish-gray, becoming brown.

Indol formation slight.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, maltose and sucrose. No acid or gas in dextrin, lactose or mannitol.

Putrefactive odor produced.

H_2S formed.

Lead acetate turned brown.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Putrefying materials.

2. **Proteus mirabilis** Hauser. (Sitz.- ber. d. phys.- mediz. Sozietät zu Erlangen, 1885, 156; *Bacillus mirabilis* Trevisan, I Generi e le Specie delle Batteriacee, 1889, 17; *Bacillus proteus mirabilis* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 276; *Bacterium mirabile* Chester, Delaware College Agr. Exp. Sta., 9th Ann. Rept., 1897, 128.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly, in pairs and frequently in long chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Irregular, spreading.

Gelatin stab: Slow, stratiform liquefaction.

Agar colonies: Gray, irregular, spreading.
Agar slant: Thin, bluish-gray, spreading over surface.
Broth: Turbid, with thin gray pellicle and sediment.
Litmus milk: Slightly acid, becoming alkaline, peptonized.
Potato: Dirty-gray, spreading.
Indol not formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose, levulose, galactose and sucrose. No acid or gas in maltose, dextrin or mannitol.
Putrefactive odor produced.
H_2S formed.
Lead acetate turned brown.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Putrefying materials.

3. **Proteus iliacus** (Ford) *comb. nov.* (*Bacillus iliacus* Ford, Studies from the Royal Victoria Hospital, Montreal, *1* (Path. II), 1903, 61; *Escherichia iliaca* Bergey et al., Manual, 1st ed., 1923, 203.)
Rods 0.75 by 3.0 to 4.0 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.
Gelatin colonies: Large, gray, translucent, spreading.
Gelatin stab: Rapid, stratiform liquefaction.
Agar colonies: Thick, white, opaque with translucent edges.
Agar slant: White, glistening, spreading.
Broth: Turbid, with thick pellicle.
Litmus milk: Acid, with coagulation. Digestion.
Potato: Abundant, yellowish-brown growth.
Indol not formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose and sucrose. No action in lactose.
Turn lead acetate brown.
No characteristic odor.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

4. **Proteus noctuarum** (White) *comb. nov.* (*Bacillus noctuarum* White, Jour. Agr. Research, *26*, 1923, 487; *Escherichia noctuarii* Bergey et al. Manual 3rd ed., 1930, 327.)
Rods with rounded ends, 0.5 by 0.7 to 1.0 micron, occurring singly and in pairs. Motile with a polar flagellum. Gram-negative.
Gelatin stab: Infundibuliform liquefaction.
Agar colonies: Circular, glistening, gray.
Agar slant: Slight grayish streak.
Broth: Turbid, with thin pellicle, and heavy sediment.

Litmus milk: Slightly acid, becoming alkaline. Reduction.

Potato: Gray, becoming yellowish. Media becomes brown. Gas is formed.

Indol not formed.

Nitrates not reduced.

Acid in dextrose, levulose, galactose, mannose, xylose, maltose, sucrose, dextrin, salicin, glycerol and mannitol. A very small amount of acid in lactose and arabinose and not in raffinose, inulin and erythrite. Slight amount of gas in dextrose, levulose, mannose, sucrose and salicin.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Causes septicemia in larvae of cutworm (*Feltia sp.*).

5. **Proteus hydrophilus** (Chester) Bergey et al. (*Bacillus hydrophilus fuscus* Sanarelli, Cent. f. Bakt., *9*, 1891, 222; *Bacterium hydrophilus fuscus* Chester, Delaware College Agr. Expt. Sta., 9th. Ann. Rept. 1897, 92; *Bacillus hydrophilus* Chester, Manual, 1901, 235; Bergey et al., Manual, 1st ed., 1923, 211.)

Weldin (Iowa State College Jour. Sci., *1*, 1927, 151) considers *Bacillus ranicida* Ernst, (Beitrage z. path. Anat. u. z. Allgemein. Path., *8*, 1890, 204) a possible synonym of *Proteus hydrophilus*; *Bacterium ranicida* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1899 (Eng. trans. 1901, 287).

Rods: 0.6 by 1.3 microns, occurring singly and in chains. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Small, circular, gray, translucent, stippled.

Gelatin stab: Napiform liquefaction.

Agar colonies: Whitish, raised, moist, stippled.

Agar slant: Thin, whitish, glassy, spreading, becoming yellowish.

Broth: Turbid, with heavy pellicle.

Litmus milk: Acid; coagulated; peptonized.

Potato: Yellowish-brown, moist, slightly raised.

Indol is formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, maltose, sucrose and mannitol. Acid but no gas in lactose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from frogs dead of septicemia ("Red leg"). Pathogenic for frogs, salamanders, fish, mice, guinea pigs and rabbits, causing hemorrhagic septicemia.

6. **Proteus ichthyosmus** (Hammer) *comb. nov.* (*Bacillus ichthyosmius* Hammer, Research Bul. 38, Iowa Agr. Sta., 1917; *Escherichia ichthyosmia* Bergey et al., Manual, 1st ed., 1923, 201.)

Rods: 0.6 to 0.8 by 1.0 to 2.1 microns, occurring singly. Motile. Gram-negative.

Gelatin stab: Liquefaction.
Agar colonies: Small, white, becoming darker with age.
Agar slant: Dirty white, viscid growth.
Broth: Turbid with gray sediment.
Litmus milk: Acid. Litmus reduced. Cultures have "fishy" odor.
Potato: Thin, glistening layer.
Indol is formed.
Nitrates reduced to nitrites.
Acid and gas formed in dextrose, levulose, galactose, maltose, sucrose, glycerol, salicin and mannitol. Lactose, dulcitol and inulin not fermented.
Aerobic, faculative.
Optimum temperature 20°C.
Habitat: Isolated from can of evaporated milk having a fishy odor.

7. **Proteus bombycis** (Bergey et al.) *comb. nov.* (*Klebsiella bombycis* Glaser, Jour. Bact., *9*, 1924, 339; *Aerobacter bombycis* Bergey et al., Manual, 3rd ed., 1930, 334.)
Rods: 0.5 by 1.5 microns. Motile. Encapsulated. Gram-negative.
Gelatin colonies: Punctiform, gray.
Gelatin stab: Liquefaction.
Agar colonies: Circular or irregular, smooth, glistening.
Agar slant: Abundant, white, smooth, glistening.
Broth: Turbid.
Litmus milk: Acid, coagulated, peptonized. Litmus reduced.
Potato: Abundant, white or with light yellow tinge.
Indol not formed.
Blood serum liquefied.
Acid and gas in dextrose, maltose, sucrose, and mannitol. No action on lactose nor dulcitol.
Starch not hydrolyzed.
Acetylmethylcarbinol is formed.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Disease of silkworms.

8. **Proteus asiaticus** (Castellani) Bergey et al. (*Bacillus asiaticus* Castellani, Cent. f. Bakt., I Abt., Orig., *65*, 1912, 262; *Salmonella asiaticus* Castellani and Chalmers, A Manual of Tropical Medicine, 1919, 940; *Bacterium asiaticum* Weldin and Levine, Abs. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 211.)
Short rods: 0.5 to 0.6 by 2.0 to 5.0 microns, occurring singly. Non-motile. Gram-negative.
Gelatin stab: No liquefaction.
Agar colonies.
Agar slant.
Broth: Turbid.
Litmus milk: Acid, becoming alkaline.

Potato.

Indol formed in slight amount.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, arabinose, maltose, sucrose, raffinose, dextrin, glycerol, mannitol, sorbitol and isodulcitol. No acid or gas in lactose, inulin or adonitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

9. **Proteus sphingidis** (White) *comb. nov.* (*Bacillus sphingidis* White, Jour. Agr. Research, *26*, 1923, 477; *Escherichia sphingidis* Bergey et al., Manual, 3rd ed., 1930, 327.)

Short rods with rounded ends, 0.5 to 0.7 by 0.8 to 1.5 microns, occurring singly and in pairs. Motile with a polar flagellum. Gram-negative.

Gelatin colonies: Small circular, gray.

Gelatin stab: Crateriform to infundibuliform liquefaction.

Agar colonies: Circular, glistening, entire, gray.

Agar slant: Slightly raised, gray, becoming yellowish-brown.

Broth: Slight turbidity with thin pellicle and friable sediment.

Litmus milk: Slow coagulation, becoming alkaline.

Potato: Slight, moist, yellowish. Media discolored.

Indol not formed.

Nitrates not reduced.

Acid and a small amount of gas in dextrose, levulose, sucrose and salicin. Acid in glycerol, mannitol, galactose, mannose, arabinose, xylose, maltose and dextrin. A slight amount of acid in lactose and arabinose in 24 hours followed by alkalinity. No action on raffinose, inulin and erythrite.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from "hornworm" larvae, *Protoparce sexta* Johan. and *P. quinquemaculata* Haw.

10. **Proteus americanus** Pacheco. (Scienca Medica, Rio de Janeiro, *6*, 1928.)

Rods occurring singly and in chains. Motile. Gram-negative.

Gelatin colonies: Circular, rugose surface.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Circular, transparent, homogeneous, slightly raised, undulate margin, slightly yellowish in color.

Agar slant: Moist, smooth, glistening.

Broth: Turbid, with pellicle and abundant sediment.

Litmus milk: Coagulation and peptonization.

Potato: Abundant, smooth, glistening.

Indol not formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, xylose, and glycerol. Galactose,

mannose, arabinose, lactose, maltose, sucrose, inulin, salicin, mannitol, dulcitol, inositol and sorbitol are not fermented.

Acetylmethylcarbinol is formed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from the blood of patients with liver abscess.

11. **Proteus ammoniae** Magath. (Jour. Infect. Dis., *43*, 1928, 181.)

Rods: 0.5 by 1.0 to 3.5 microns, occurring singly. Motile. Gram-negative.

Gelatin stab: Liquefaction.

Agar colonies: Moist, bluish-gray, somewhat shiny, circular to ameboid.

Agar slant: Moist, bluish-gray streak.

Broth:

Litmus milk: Acid, becoming alkaline. Rapid peptonization.

Potato:

Indol is formed by some strains.

Nitrates.

Acid and gas are formed in dextrose, galactose, xylose and trehalose. Acid but no gas formed in glycerol. No action in maltose, lactose, sucrose, mannitol, dulcitol, inulin, inositol, salicin, arabinose, rhamnose and dextrin.

Acid is formed in glycerol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from urine in cystitis.

12. **Proteus valeriei** (Weldin and Levine) Bergey et al. (Valérie 21, Boycott, Jour. Hyg., *6*, 1906, 33; *Bacillus asiaticus mobilis* Castellani, Ann. di. Med. Nov. e. Colon., *11*, 1916, 453; *Salmonella asiaticus mobilis* Castellani and Chalmers, A Manual Tropical Medicine, 1919, 940; *Bacterium valeriei* Weldin and Levine, Abs. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 211.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly and in pairs. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies.

Agar slant.

Broth: Turbid.

Litmus milk: Acid; not coagulated.

Potato.

Indol is formed.

Nitrates.

Acid and gas in dextrose, levulose, galactose, arabinose, sucrose, maltose, raffinose, dextrin, mannitol, sorbitol and dulcitol. No acid or gas in lactose, salicin or inulin.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from intestine of a patient cared for by Dr. Valérie. Occurs in human intestine. Agglutinins are not completely absorbed from serum by members of the paratyphoid group.

13. **Proteus pseudovaleriei** Assis. (Jour. of Hyg., *27*, 1927, 108.)

Rods of variable length, from cocciform to long threads. Motile. Gram-negative.

Gelatin stab: Surface growth with visible growth in stab. No liquefaction.

Agar colonies: Circular, transparent, grayish-white.

Agar slant: Grayish-white, spreading, transparent.

Broth: Turbid, with whitish ring and grayish sediment. Disagreeable odor.

Litmus milk: Slow, partial coagulation. Decolorized.

Potato: Luxuriant, whitish growth.

Indol is formed.

Nitrates.

H_2S is formed.

Acid and gas in dextrose, levulose, galactose, maltose, arabinose, xylose, salicin, dextrin, mannitol, and isodulcitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Blood, in fever resembling typhoid.

Genus XXI. Salmonella *Lignières, 1900.*

Motile or non-motile forms. Occur in the intestinal canal of animals in various types of acute, inflammatory conditions. Attack numerous carbohydrates with the formation of both acid, or acid and gas but not lactose, sucrose and salicin. In general do not form acetylmethylcarbinol.

The type species is *Salmonella suipestifer* (Kruse) Castellani and Chalmers.

Key to the species of the genus Salmonella.

A. Acid or acid and gas in mannitol.
  1. Acid or acid and gas in xylose.
    a. Acid and gas in dulcitol.
      b. No acid or gas in sorbitol.
        1. *Salmonella suipestifer.*
      bb. Acid and gas in sorbitol.
        2. *Salmonella columbensis.*
    aa. No action in dulcitol.
      3. *Salmonella pullorum.*
    aaa. Acid or acid and gas in dulcitol.
      b. No acid or gas in inositol.
        c. No acid or gas in dextrin.

4. *Salmonella abortivo-equina.*
5. *Salmonella icteroides.*

cc. Acid but no gas in dextrin.

6. *Salmonella gallinarum.*

ccc. Acid and gas in dextrin.

7. *Salmonella enteritidis.*

bb. Acid or acid and gas in inositol.

c. Acid or acid and gas in dextrin.

8. *Salmonella schottmuelleri.*
9. *Salmonella anatis.*

cc. No acid or gas in dextrin.

10. *Salmonella aertrycke.*

2. No acid or gas in xylose.

a. Acid and gas in dulcitol.

b. Acid and gas in inositol.

c. Acid and gas in dextrin.

d. No acid or gas in raffinose.

11. *Salmonella typhimurium.*

dd. Acid and gas in raffinose.

12. *Salmonella veboda.*

cc. No acid or gas in dextrin.

13. *Salmonella watareka.*

bb. No acid or gas in inositol.

c. Acid and gas in dextrin.

14. *Salmonella paratyphi.*
15. *Salmonella hirschfeldii.*
16. *Salmonella psittacosis.*

cc. No acid or gas in dextrin.

d. Acid and gas in maltose.

17. *Salmonella archibaldii.*

aa. Acid and gas in dulcitol.

18. *Salmonella woliniae.*

AA. No acid or gas in mannitol.

1. Acid and gas in maltose and dextrin.

19. *Salmonella giumai.*

2. No acid or gas in maltose or dextrin.

a. Acid and gas in levulose.

20. *Salmonella morgani.*

aa. No acid or gas in levulose.

21. *Salmonella foetida.*

1. **Salmonella suipestifer (Kruse) Castellani and Chalmers.** (Probably not the *Bacillus* of swine plague, Klein, Report of the Medical Officer of the Local Gov. Bd., England, 1877–78, Supplement, p. 168; *Bacterium* of swine plague, Salmon, U. S. Dep. Agr., Bur. An. Ind., An. Rep., 1885, 212; *Bacterium* of hog cholera, Salmon, *ibid.*, 1886, 20; Bakterium der schwinepest,

Selander, Cent. f. Bakt., *3*, 1888, 361; *Pasteurella salmoni* Trevisan, I Generi e le Specie delle Batteriacee, 1889, 21; *Bacterium cholerae suis* Th. Smith, U. S. Dep. Agr., Bur. An. Ind., Bull. 6, 1894, 9; Swinefeverbacillus, Klein, Cent. f. Bakt., I Abt., *18*, 1895, 105; *Bacillus suipestifer* Kruse in Flügge, Die Mikroorganismen, *2*, 1896, 401; *Bacterium cholerae suum* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 233; *Bacillus cholerae suum* Migula, System der Bakterien, 1900, 759; Le microbe du hog-choléra, Lignaries, Bull. d. l. Soc. d. Cent. Méd. Vét., see, Rec. de méd. vét., Paris, Sér. 8, *7*, 1900, 389; *Bacillus salmoni* Chester, Manual of Determinative Bacteriology, 1901, 210; *Bacterium intestinale suis* Le Beaye and Guggenheim, Manuele Pratique de Diagnostic Bactériologique, Viget Freres, 1914; *Bacillus suis* Krumwiede, Kohn and Valentine, Jour. Med. Res., *38*, 1918, 89; Bacterium (*Salmonella*) *cholera suis* Buchanan, Jour. Bact., *3*, 1918, 53; Castellani and Chalmers, A Manual of Tropical Medicine, 3rd ed., 1919, 939; *Salmonella cholerae suis* Weldin, Iowa State College of Science, *1*, 1927, 155.)

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly and staining deeply at the poles. Motile with four to five peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish, smooth, flat, glistening, irregular margin.

Gelatin stab: Flat, grayish surface growth. No liquefaction.

Agar colonies: Grayish, moist, smooth, translucent.

Agar slant: Smooth, moist, grayish, translucent.

Broth: Turbid, with thin pellicle and grayish-white sediment.

Litmus milk: Slightly acid, becoming alkaline, opalescent, translucent to yellowish-gray.

Potato: Grayish-white streak becoming brownish.

Acid and gas in dextrose, levulose, galactose, mannose, arabinose, xylose, maltose, glycerol, mannitol, dulcitol, sorbitol and isodulcitol. Inositol may be fermented. Lactose, sucrose, inulin, salicin, dextrin, raffinose, trehalose or sorbitol are not attacked.

Indol not formed.

Nitrates.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Associated with "hog cholera" and generally regarded as a secondary invader. Infectious for mice and rabbits on subcutaneous inoculation.

2. **Salmonella columbensis** (Castellani) Castellani and Chalmers. (*Bacterium columbense* Castellani, Cent. f. Bakt., I Abt., Orig., *74*, 1914, 197; *Bacillus columbensis* Castellani, Jour. Trop. Med. and Hyg., *20*, 1917, 181; Castellani and Chalmers, Ann. Inst. Past., *34*, 1920, 609.)

Rods: 0.5 to 0.6 by 2.0 to 5.0 microns, with rounded ends, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, gray.

Gelatin stab: No liquefaction.

Agar colonies: Circular, gray, entire to lobate.

Agar slant: Luxuriant, gray, plumose.

Broth: Turbid, with delicate gray pellicle and sediment.

Litmus milk: Acid, becoming alkaline, with reduction of litmus. Rarely coagulated.

Potato: Dirty-gray streak.

Indol formed.

Nitrates not reduced.

Acid and gas in dextrose, levulose, galactose, arabinose, xylose, maltose, dextrin, salicin, glycerol, mannitol, dulcitol, isodulcitol and sorbitol. No acid or gas in lactose, sucrose, raffinose, adonitol or inositol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from cases of fever resembling somewhat typhoid fever.

3. **Salmonella pullorum** (Rettger) Bergey et al. (*Bacterium pullorum* Rettger, Jour. Med. Res., *21*, (N. S. 16), 1909, *117*; Also see, Rettger, N. Y. Med. Jour., *71*, 1900, 803; *ibid.* *73*, 1901, 267; Rettger and Harvey, Jour. of Med. Res., *18*, 1908, 277; *Bacillus pullorum* Smith and Ten Broeck, Jour. Med. Res., *31*, (N. S. 26), 1915, 547; Bergey et al., Manual, 1st ed., 1923, 218.)

Rods: 0.3 to 0.5 by 1.0 to 2.5 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Grayish-white, moist, lobate, with grape-leaf surface.

Gelatin stab: Slight, grayish surface growth. No liquefaction.

Agar colonies: Grayish-white, smooth, glistening, entire to undulate.

Agar slant: Develops as discrete, translucent colonies.

Broth: Turbid.

Litmus milk: Acid, becoming alkaline. No coagulation.

Potato: Slow development, grayish.

Indol not formed. Nitrates reduced.

Acid and gas in dextrose, levulose, galactose, mannose, arabinose, mannitol and isodulcitol. Does not attack lactose, sucrose, maltose, xylose, dextrin salicin, raffinose, sorbitol, adonitol, dulcitol or inositol.

Acetylmethylcarbinol not formed. H_2S is formed.

Aerobic, facultative. Optimum temperature 37°C.

Habitat: The cause of "white diarrhea" in *old* chickens and septicemia in *young* chicks.

4. **Salmonella abortivo-equina** (Good and Corbett) Bergey et al. (*Bacillus abortivus equinus* Good and Corbett, Jour. Inf. Dis., *13*, 1913, 53; *Bacillus abortus equi* Meyer and Boerner, Jour. Med. Res., *29*, 1913, 330; *Bacillus abortivo-equinus* Good and Corbett, Jour. Inf. Dis., *18*, 1916, 586; *Bacillus abortus equinus* Weiss and Rice, Jour. Med. Res., *35*, 1917, 403; *Bacterium abortum-equi* Holland, Jour. Bact., *5*, 1920, 221; Bergey et al., Manual, 1st ed., 1923, 217; *Salmonella abortus-equi* Bergey et al., Manual, 2nd ed., 1925, 236.)

Rods: 0.2 to 0.5 by 0.5 to 1.5 microns, occurring singly, occasionally in pairs. Motile, with peritrichous flagella. Gram-negative.

Gelatin colonies: Very small, circular, slightly lobate, transparent, flat, center darker with fine, granular, concentric rings and slightly wrinkled surface.

Gelatin stab: Surface growth like colonies. Filiform growth in stab. No liquefaction.

Agar colonies: Small, circular, grayish-white, flat, concentrically ringed, center raised, granular, margin, irregular.

Agar slant: Grayish-white, glistening, somewhat wrinkled.

Broth: Turbid, with thin pellicle and viscid sediment.

Litmus milk: Slightly acid, becoming alkaline, translucent, yellowish-gray.

Potato: Moist, pale yellow on alkaline medium. No growth on acid medium.

Acid and gas in dextrose, levulose, galactose, mannose, arabinose, xylose, maltose, mannitol, dulcitol, isodulcitol and sorbitol. No acid or gas in lactose, sucrose, dextrin, salicin, adonitol or inositol.

Indol not formed.

Nitrates not reduced.

H_2S is formed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Causes abortion in mares. Infectious for guinea pigs, rabbits, goats, pigs and cows, producing abortion in pregnant females.

5. **Salmonella icteroides** (Sanarelli) Bergey et al. (Bacillo icteroide, Sanarelli, Il Policlinico, *4*, 1897, 412; *Bacillus icteroides* Sanarelli, British Med. Jour., July 3, 1897, 7; *Bacterium icteroides* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1899 (English ed. 1901, 197); Bergey et al., Manual, 1st ed., 1923, 218.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Gray, smooth, entire.

Agar slant: Gray, smooth, plumose.

Broth: Turbid, with gray sediment.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Dirty-white, smooth.

Indol may or may not be formed.

Nitrates reduced.

Acid and gas in dextrose, levulose, galactose, maltose, mannitol, sorbitol and acid in arabinose, xylose, raffinose, salicin and dulcitol. No action on dextrin.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: First isolated from yellow fever cadavers, but found to have no etiologic relation to the disease.

6. **Salmonella gallinarum** (Klein) Bergey et al. (*Bacillus gallinarum* Klein, Cent. f. Bakt., *5*, 1889, 689; *Bacillus phasiani septicus* Kruse in Flügge, Die Mikroorganismen, 1896, 410; *Bacillus sanguinarum* Moore, U. S. Dep. Agr., Bur. An. Ind., Bull. No. 8, 1895; *Bacterium gallinarum* Migula, System der Bakterien, 1900, 371; *Bacillus pseudo-cholerae gallinarum* Trincas, Giorn. della R. Soc. It. d'Igiene, 1908, 385; *Bacillus typhi gallinarum* Pfeiler and Rehse, Mitt. K. W. Inst. f. Landw. Bromberg., *5*, 1913, 306; *Eberthella sanguinaria*, Bergey et al., Manual, 1st ed., 1923, 231; Bergey et al., Manual, 2nd. ed., 1925, 236.)

Rods: 0.4 to 0.6 by 0.8 to 1.6 microns, with rounded ends, occurring singly or (in blood) in short chains, frequently showing peripheral but not bipolar staining. Non-motile. Gram-negative.

Gelatin colonies: Small, grayish-white, finely granular, circular, entire.

Gelatin stab: Slight, grayish-white surface growth with slight grayish, filiform growth in stab. No liquefaction.

Agar colonies: Moist, grayish, circular, entire.

Agar slant: Thin, gray streak, with irregular margin, moist, glistening.

Broth: Turbid with heavy, flocculent sediment.

Litmus milk: Reaction unchanged, becoming translucent. No coagulation.

Potato: Slight grayish growth.

Indol not formed.

Nitrates reduced.

Acid but no gas in dextrose, levulose, galactose, mannose, xylose, arabinose, maltose, dextrin, mannitol, dulcitol and isodulcitol. Lactose, sucrose, glycerol, salicin and sorbitol are not attacked.

H_2S is sometimes formed.

Aerobic, facultative.

Optimum temperature 37°C.

Agglutinates with *Eberthella typhosa* and *Salmonella pullorum* immune serums.

Habitat: The causative agent of fowl typhoid (clearly to be distinguished from fowl cholera), and identical with Moore's "infectious leukemia" of fowls. Infectious for rabbits and all poultry, canaries and certain wild birds (quail, grouse, pheasants) by feeding or by injection.

7. **Salmonella enteritidis** (Gaertner) Castellani and Chalmers. (*Bacillus enteritidis* Gaertner, Correspond. d. Allgemein. Artzl. Vereins Thuringen, *17*, 1888, 573; *Klebsiella enteritidis* De Toni and Trevisan, Saccardo, Sylloge Fungorum, *8*, 1889, 923; *Bacillus gaertner* Morgan, Brit. Med. Jour., *1*, 1905, 1257; Manual of Tropical Medicine, 1919, 939.)

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly, in pairs and occasionally in short chains. Motile, with peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, gray, translucent, granular, entire.

Gelatin stab: Abundant surface growth. No liquefaction.

Agar colonies: Circular, gray, translucent, moist, smooth, entire.

Agar slant: Grayish-white, opalescent, smooth, moist, undulate.

Broth: Turbid, with thin pellicle and grayish-white sediment.

Litmus milk: Slightly acid, becoming alkaline, opalescent, translucent to yellowish-gray.

Potato: Abundant, moist, yellowish-brown to brown.

Acid and gas in dextrose, levulose, galactose, mannose, arabinose, xylose, maltose, trehalose, dextrin, glycerol, mannitol, dulcitol and sorbitol. No acid or gas in lactose, sucrose, inulin, salicin, raffinose, adonitol and inositol.

Indol not formed.

Nitrates reduced to nitrites.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: First isolated from intestines in epidemic of meat poisoning Widely distributed, occurring in both domestic and wild animals.

8. **Salmonella schottmuelleri** (Winslow et al.) Bergey et al. (*Bacillus paratyphi alcaligenes* Schottmüller, Deutsche Med. Wochenschr., 1900, 511; Seiffert, Zeitschr. f. Hyg., *63*, 1909, 273; *Bacterium paratyphi* type B, Kayser, Cent. f. Bakt., I. Abt., Orig., *31*, 1904, 426; *Bacillus paratyphosus B*, Wilson, Jour. Hyg., *8*, 1908, 543; *Bacterium paratyphosum B*, Le Blaye and Guggenheim, Manuele Pratique de Diagnostic Bacteriologique, Viget Freres, 1914; *Bacillus schottmülleri* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 479; *Bacterium schottmülleri* Holland, Jour. Bact., *5*, 1920, 215; *Salmonella paratyphi B*, Castellani and Chalmers, Manual of Tropical Medicine, 1919, 939; Bergey et al., Manual, 1st ed., 1923, 213.)

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly and in pairs. Motile, with peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Small, circular, bluish-gray, transparent, homogeneous, entire to undulate.

Broth: Turbid, with thin gray pellicle and sediment. Fecal odor.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Grayish-white, viscous.

Indol not formed.

Nitrates not reduced.

Acid and gas in dextrose, levulose, galactose, mannose, arabinose, xylose, maltose, dextrin, trehalose, glycerol, mannitol, dulcitol, sorbitol, isodulcitol and inositol. No acid or gas in lactose, sucrose, inulin, salicin or adonitol and usually not in raffinose.

Turns lead acetate brown.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The cause of paratyphoid fever. Occurs in food poisoning where meat from infected animals is used.

9. **Salmonella anatis** (Rettger and Scoville) Bergey et al. (*Bacterium anatis* Rettger and Scoville, Abs. Bact., *3*, 1919, 8; not *Bacterium anatis* Cornil and Loupet, Compt. rend. l'Acad. des. Sci. Paris, *106*, 1888, 1737; *Bacterium anatum* Rettger and Scoville, Jour. of Infect. Dis., *26*, 1920, 217; *Escherichia anata* Bergey et al., Manual, 1st ed., 1923, 198; Bergey et al., Manual, 2nd ed., 1925, 238.)

Rods: 0.5 by 1.0 to 2.0 microns occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: No surface growth. Slight growth along stab. No liquefaction.

Agar colonies: Grayish-white, undulate, contoured.

Agar slant: Moderately abundant, grayish opaque, slightly wrinkled.

Broth: Turbid, with slight pellicle.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Heavy, moist grayish, becoming light brown.

Indol not formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, arabinose, xylose, maltose, trehalose, dextrin, mannitol, dulcitol, sorbitol, isodulcitol and inositol. No acid or gas in lactose, sucrose, raffinose, salicin or adonitol.

H_2S is formed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Produces a disease in ducklings which is known as "keel."

10. **Salmonella aertrycke** (DeNobele) Castellani and Chalmers. (*Bacillus aertrycke* DeNobele, Ann. de la soc. de Gand, 1898 and 1901; *Bacillus para-aertrycke* Castellani, Ann. di Med. Nav. e. Colon., *11*, 453; Castellani and Chalmers, *ibid.*, 939; *Bacterium aertrycke* Weldin and Levine, Abs. Bact., *7*, 1923, 13.)

Short rods: 0.5 to 6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Gray, entire, smooth, glistening.

Agar slant: Gray, smooth, moist, glistening.

Broth: Turbid, with slight gray sediment.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Limited, dirty-white, glistening.

Indol rarely formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, mannose, xylose, maltose, trehalose, mannitol, dulcitol, isodulcitol, sorbitol and inositol. Acid formed in glycerol. No action on lactose, sucrose, raffinose, dextrin, salicin, inulin, or sorbitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Found in intestinal tract of man and animals. Meat poisoning. Agglutinins for *S. schottmuelleri* are not completely absorbed from *S. schottmuelleri* immune serum.

11. **Salmonella typhimurium** (Loeffler) Castellani and Chalmers. (*Bacterium typhi murium* Löffler, Cent. f. Bakt., *11*, 1892, 129; Manual of Tropical Medicine, 1919, 939.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Small, circular, grayish, granular, becoming yellowish-brown.

Gelatin stab: Flat surface growth. No liquefaction.

Agar colonies: Small, circular, grayish, entire to undulate.

Agar slant: Filiform, grayish, moist, entire.

Broth: Turbid.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Grayish-white streak.

Indol formation doubtful.

Nitrates not reduced.

Acid and gas in dextrose, levulose, galactose, arabinose, maltose, dextrin, mannitol, sorbitol and inositol. No action on lactose, sucrose, raffinose, inulin, salicin or adonitol. Acid in glycerol.

Turns lead acetate brown.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Associated with a fatal epidemic in mice. Pathogenic for house and field mice on feeding and subcutaneous injection.

12. **Salmonella veboda** (Castellani) Castellani and Chalmers. (*Bacillus veboda* Castellani, Jour. Trop. Med. and Hyg., *20*, 1917, 181; Castellani and Chalmers, A Manual of Tropical Medicine, 1919, 939; *Bacterium veboda* Weldin and Levine, Abs. Bact., *7*, 1923, 13.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Gray, entire, glistening.

Agar slant: Smooth, gray, glistening.

Broth: Turbid.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Dirty-white, smooth, glistening.

Indol not formed.

Nitrates not reduced.

Acid and gas in dextrose, levulose, galactose, arabinose, maltose, dextrin, raffinose, dulcitol, sorbitol and inositol and usually salicin. Acid formed in isodulcitol and mannitol. No acid or gas in lactose, sucrose, or adonitol.

Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

13. **Salmonella watareka** (Castellani and Chalmers) Bergey et al. (*Bacillus watareka* Castellani, Report of the Advisory Committee for the Tropical Diseases Research Fund for 1912, London, 1913; *Bacterium watareka* Weldin and Levine, Abs. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 219.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.
Gelatin colonies.
Gelatin stab: No liquefaction.
Agar colonies: Gray, smooth, entire.
Agar slant: Gray, plumose, glistening.
Broth: Turbid.
Litmus milk: Acid.
Potato: Dirty-gray, smooth, glistening.
Indol is formed.
Nitrates reduced to nitrites.
Acid and gas in dextrose, levulose, galactose, arabinose, maltose, raffinose, glycerol, mannitol, dulcitol, isodulcitol, sorbitol and inositol. No action on dextrin, adonitol or salicin.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

14. **Salmonella paratyphi** (Kayser) Bergey et al. (*Bacterium paratyphi* Kayser, Cent. f. Bakt., I Abt., Orig., *31*, 1902, 426; *Bacterium paratyphi* type A, Kayser, *ibid.*; *Bacillus paratyphosus A* Wilson, Jour. Hyg., *8*, 1908, 543; *Bacillus paratyphosus* Winslow, Kligler and Rothberg, Jour. Bact., *4*, 1919, 429; *Salmonella paratyphi A* Castellani and Chalmers, A Manual of Tropical Medicine, 1919, 939; Bergey et al., Manual, 1st ed., 1929, 240.)

Rods: 0.6 by 3.0 to 4.0 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.
Gelatin colonies: Bluish-gray, homogeneous, smooth, entire.
Gelatin stab: Fair surface growth. No liquefaction.
Agar colonies: Grayish, homogeneous, smooth, glistening, entire to slightly undulate.
Agar slant: Filiform, grayish, smooth, glistening.
Broth: Turbid, with slight grayish sediment.
Litmus milk: Slightly acid, becoming slightly alkaline in a week.
Potato: Limited, dirty-white streak.
Acid and gas in dextrose, levulose, galactose, mannose, arabinose, maltose, trehalose, dextrin, glycerol, mannitol, dulcitol, isodulcitol and sorbitol. No acid or gas in lactose, sucrose. raffinose, xylose, salicin, inulin, adonitol or inositol.

Indol not formed.
Nitrates not reduced.
H_2S not formed. Lead acetate not turned brown.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: The cause of paratyphoid fever.

15. **Salmonella hirschfeldii** Weldin. (Paratyphoid C, Hirshfeld, The Lancet, *1*, 1919, 296; Weldin, Iowa State Jour. of Sci., *1*, 1927, 121.)

Morphologically and culturally similar to *Salmonella enteritidis* but differs in its serologic reactions.

Litmus milk: Slightly acid, becoming alkaline.

Indol rarely formed.

Acid and gas in dextrose, levulose, maltose, arabinose, xylose, dextrin, mannitol and dulcitol. No action on lactose, sucrose, salicin, adonitol, sorbitol or inositol.

Is not agglutinated by *Salmonella enteritidis* serum.

Habitat: Intestinal tract of man in enteric fever.

16. **Salmonella psittacosis** (Nocard) Castellani and Chalmers. (*Bacillus psittacosis* Nocard, Conseil d. Hygiene Publique et Salubrite du Dept. du Seine, Seance, March 24, 1893; *Bacterium psittacosis* Le Blaye and Guggenheim, Manuele Pratique de Diagnostic Bacteriologique, Viget Freres, 1914; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 939.)

Rods: 0.4 to 0.6 by 1.0 to 1.5 microns, occurring singly. Motile, with peritrichous flagella. Gram-negative.

Gelatin colonies: Small, bluish, glistening, becoming porcelain-white.

Gelatin stab: No liquefaction.

Agar colonies: Small, grayish, entire to undulate.

Agar slant: Filiform, grayish, glistening, undulate.

Broth: Turbid, with thin pellicle.

Litmus milk: Acid, then alkaline. No coagulation.

Potato: Slight, grayish streak.

Indol not formed.

Nitrates.

Acid and gas in dextrose, levulose, galactose, arabinose, maltose, raffinose, dextrin, mannitol, dulcitol and sorbitol. No acid or gas in xylose, lactose, sucrose, salicin inositol or adonitol.

Acetylmethylcarbinol not formed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The causative organism of pneumonia in parrots. Affecting persons associated with sick parrots.

17. **Salmonella archibaldii** Castellani and Chalmers. (Castellani and Chalmers, Manual of Tropical Medicine, 1919, 940.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies.

Agar slant.

Broth: Turbid.

Litmus milk: Acid, becoming alkaline.

Potato.

Indol is formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose, levulose, galactose, maltose, mannitol, dulcitol and sorbitol. No acid or gas in lactose, sucrose, raffinose, salicin, xylose, dextrin, adonitol or inositol or sorbitol.

Acetylmethylcarbinol formed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

18. **Salmonella woliniae** (Castellani) Castellani and Chalmers. (*Bacillus woliniae* Castellani, Jour. Trop. Med. and Hyg., *20*, 1917, 181; *Bacterium woliniae* Weldin and Levine, Abs. Bact., 7, 1923, 13; Manual of Tropical Medicine, 1919, 939.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies.

Agar slant.

Broth: Turbid.

Litmus milk: Slightly acid, frequently becoming alkaline.

Potato.

Indol not formed.

Nitrates not reduced.

Acid and gas in dextrose, galactose, maltose, glycerol, mannitol and dulcitol. No action in levulose, raffinose, arabinose, dextrin, dulcitol, adonitol, inositol or salicin.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

19. **Salmonella giumai** (Castellani) Bergey et al. (*Bacillus giumai* Castellani, Cent. f. Bakt., I Abt., *65*, 1912, 262; *Wesenbergus giumai* Castellani and Chalmers, Manual of Tropical Medicine, 1919, 940; *Bacterium giumai* Weldin and Levine, Abs. Bact., 7, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 220.)

Short rods: 0.5 to 0.6 by 1.0 to 3.0 microns, occurring singly. Non-motile. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies.
Agar slant.
Broth: Turbid.
Litmus milk: Slightly acid, becoming slightly alkaline.
Potato.
Indol not formed.
Nitrates not reduced.
Acid and gas in dextrose, levulose, galactose, arabinose, maltose, dextrin, salicin, sorbitol and isodulcitol. Acid in glycerol. No action on sucrose, xylose, raffinose, mannitol, dulcitol or adonitol.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal in enteric fever in the tropics.

20. **Salmonella morganii** (Winslow et al.) Castellani and Chalmers. (Organism No. 1., Morgan, Brit. Med. Jour., *1*, 1906, 908; *Bacillus morgani* Winslow, Kligler, Rothberg, Jour. Bact., *4*, 1919, 429; *Bacterium morgani* Holland, Jour. Bact., *5*, 1920, 215, Castellani and Chalmers, Manual of Tropical Medicine, 1919, 939.)
Common name: Morgan's bacillus.
Rods: 0.4 to 0.6 by 1.0 to 2.0 microns, occurring singly. Motile with peritrichous flagella. (Also non-motile varieties.) Gram-negative.
Gelatin colonies: Bluish-gray, homogeneous, smooth, entire.
Gelatin stab: No liquefaction.
Agar colonies: Grayish or bluish-white, circular, entire.
Agar slant: Grayish-white, smooth, glistening.
Broth: Turbid.
Litmus milk: Neutral, or becoming alkaline.
Potato: Dirty-white, limited.
Indol is formed.
Nitrates not reduced.
Acid and gas in dextrose, levulose, galactose and glycerol. Rarely in xylose. Does not attack lactose, sucrose, maltose, arabinose, raffinose, dextrin, xylose, salicin, mannitol, dulcitol, sorbitol, adonitol or inositol.
Lead acetate turned brown.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: In intestinal canal in normal or diarrheal stools.

21. **Salmonella foetida** Bergey et al. (*Cocco-bacillus foetidus ozenae* Perez, Ann. de l'Institut Pasteur, *13*, 1899, 937; Bergey et al., Manual, 1st ed., 1923, 220; *Escherichia foetida* Bergey et al., Manual, 2nd ed., 1925, 22.)
Rods: 1.0 by 1.0 to 4.0 microns, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: Surface colonies gray; deep colonies mahogany brown.
Gelatin stab: No liquefaction.
Agar colonies: Moist, circular, translucent, becoming yellowish-brown.

Agar slant: Moist, translucent, plumose, undulate, becoming yellowish-brown.

Broth Turbid.

Litmus milk: Slightly acid; not coagulated.

Potato: Moist, gray to faintly yellow streak.

Indol is formed.

Nitrates reduced to nitrites.

Acid and gas in dextrose. No action on mannitol, levulose, maltose, dextrin, lactose, sucrose, glycerol and inulin.

Cultures have characteristic odor due to formation of mercaptan.

Pathogenic.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Chronic rhinitis. Found in nasal exudate from cases of ozena.

Genus XXII. **Eberthella** *Buchanan, 1918.*

Motile rods, generally occurring in the intestinal canal of man, usually in different forms of enteric inflammation. Attack a number of carbohydrates with the formation of acid but no gas. Do not form acetylmethylcarbinol.

The type species is *Eberthella typhosa* (Zopf) Weldin.

Key to the species of genus **Eberthella.**

1. Gelatin not liquefied.
   - a. No acid formed in lactose.
     - b. No acid formed in sucrose.
       - c. Acid formed in mannitol.
         - 1. *Eberthella typhosa.*
       - cc. No acid formed in mannitol.
         - 2. *Eberthella tarda.*
     - b. Acid formed in sucrose.
       - 3. *Eberthella kandiensis.*
       - 4. *Eberthella talavensis.*
   - aa. Acid formed in lactose.
     - b. Acid formed in mannitol.
       - c. No acid formed in salicin.
         - 5. *Eberthella oxyphila.*
     - bb. No acid formed in mannitol.
       - c. Acid formed in salicin.
         - 6. *Eberthella bentotensis.*
         - d. No acid formed in dulcitol
           - 7. *Eberthella belfastiensis.*
         - dd. Acid formed in dulcitol.
           - 8. *Eberthella pyogenes.*

2. Gelatin liquefied.
   a. Acid formed in sucrose.
      b. Acid formed in lactose.
         9. *Eberthella oedematiens.*
      bb. No acid formed in lactose.
         10. *Eberthella enterica.*
   aa. No acid formed in sucrose.
      b. Milk acid; coagulated.
         11. *Eberthella dubia.*
         c. Nitrates not reduced.
            12. *Eberthella chylogena.*
      bb. Milk unchanged.
         13. *Eberthella xenopa.*

1. **Eberthella typhosa** (Zopf) Weldin. (Bacillus der abdominal Typhus, Eberth, Virchow's Archiv., *81*, 1880, *83*, 1881; Typhus bacillen, Gaffky, Mitteil. a. d. Kaiserl. Gesundheitsamte, *2*, 1884, 372; *Bacillus typhosus* Zopf, Die Spaltpilze, 3 Aufl., 1885, 126; *Bacillus typhi* Schroeter, Cohn's Kryptogamen Flora v. Schlesien, *3*, 1886, 165; *Bacillus typhi abdominalis* Flügge, Die Mikroorganismen, 1886, 198; *Vibrio typhosus* Trevisan, Gen. e. spec. d. Batteriacee, 1889, 23; *Bacterium* (*Eberthella*) *typhi* Buchanan, Jour. Bact., *3*, 1918, 53; *Eberthus typhosus* Castellani and Chalmers, Manual of Tropical Medicine, 1919, 936; *Eberthella typhi* Bergey et al., Manual, 1st ed., 1923, 223; Weldin, Iowa State College Jour. of Sci., *1*, 1927, 170; not *Bacillus typhosus* Klebs, Handbuch d. path. Anat., 1880.)

Rods: 0.6 to 0.7 by 2.0 to 3.0 microns, occurring singly and in pairs, occasionally in short chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish, transparent to opaque, with leaf-like surface markings.

Gelatin stab: Thin, white, opalescent. No liquefaction.

Agar colonies: Grayish, transparent to opaque.

Agar slant: Whitish-gray, glistening, echinulate, entire to undulate.

Broth: Turbid, with moderate sediment and delicate pellicle in old cultures.

Litmus milk: Slight, transient acidity, followed by a return to neutral or to slight alkalinity.

Potato: Delicate, moist, slightly spreading, barely visible growth.

Acid in dextrose, levulose, galactose, xylose, maltose, raffinose, dextrin, glycerol, mannitol and sorbitol. No action on lactose, sucrose, inulin, inositol, salicin and usually arabinose and dulcitol.

Indol not formed.

Nitrates reduced to nitrites.

No characteristic odor.

Lead acetate turned brown.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The cause of typhoid fever. Pathogenic for laboratory animals on subcutaneous or intravenous injection.

2. **Eberthella tarda** Assis. (Boletin do Inst. Vital Brazil, *5*, 1928.)

Rods: 0.2 to 0.4 by 1.8 to 2.0 microns, in older cultures longer forms are seen. Occur singly, showing bipolar staining. Motile. Gram-negative.

Gelatin colonies: Circular, finely granular, undulate margin.

Gelatin stab: No liquefaction.

Agar colonies: Circular, glistening, transparent.

Agar slant: Delicate, grayish, butyrous.

Broth: Turbid, with delicate pellicle, and grayish deposit, possessing disagreeable odor.

Litmus milk: Slightly acid.

Potato: Moist, grayish streak.

Indol is formed.

Nitrates are reduced.

Acid in dextrose, galactose, maltose, lactose and salicin.

Not agglutinated with antityphoid serum.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal of patients suffering from clinical dysentery.

3. **Eberthella kandiensis** (Castellani) Bergey et al. (*Eberthus kandiensis* Castellani and Chalmers, Manual of Tropical Medicine, 1919, 936; *Bacillus kandiensis* Castellani, Cent. f. Bakt., I Abt., *65*, 1912, 262; *Bacterium kandiensis* Weldin and Levine, Abs. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 225.)

Rods: 0.4 to 0.5 by 1.0 to 1.5 microns, occurring singly. Motile possessing peritrichous flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: No liquefaction.

Agar colonies: Gray, smooth, raised, entire.

Agar slant: Gray, plumose, smooth, glistening.

Broth: Turbid.

Litmus milk: Slightly acid, becoming alkaline.

Potato: Dirty-gray, moist.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, sucrose, glycerol, mannitol and inositol. Does not attack arabinose, maltose, lactose, dextrin, inulin, salicin, raffinose, dulcitol or sorbitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

4. **Eberthella talavensis** (Castellani) Bergey et al. (*Bacillus talavensis* Castellani, Cent. f. Bakt., I Abt., *65*, 1912, 262; *Eberthus talavensis* Castellani and Chalmers, Manual of Tropical Medicine, 1919, 936; *Bacterium talavensis* Weldin and Levine, Abs. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 225.)

Rods: 0.5 by 1.0 to 1.25 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Gray, raised, smooth, entire.

Agar slant: Gray, smooth, glistening.

Broth: Turbid.

Litmus milk: Alkaline.

Potato: Dirty-white, smooth, glistening.

Indol is formed.

Nitrates reduced to nitrites.

Acid formed in dextrose, levulose, galactose, sucrose, salicin, glycerol and inositol. Does not attack arabinose, maltose, lactose, dextrin, inulin, raffinose, mannitol, dulcitol or sorbitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal. A possible cause of enteric fever.

5. **Eberthella oxyphila** (Ford) Bergey et al. (*Bacterium oxyphilum* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, No. 5, 1903, 49; Bergey et al., Manual, 1st ed., 1923, 224.)

Rods: 0.75 by 2.0 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Irregular, circular to oval, presenting "broken glass" appearance.

Gelatin stab: Filiform growth in stab. No liquefaction.

Agar colonies: Circular, opaque, with grayish-white center, homogeneous, showing radiate structure.

Agar slant: Abundant, thick, white.

Broth: Turbid, with slight sediment.

Litmus milk: Acid, with coagulation.

Potato: Luxuriant, brownish growth.

Indol not formed.

Nitrates reduced to nitrites.

Acid in dextrose.

No characteristic odor.

Lead acetate turned brown.

Aerobic, facultative.

Habitat: Intestinal canal.

6. **Eberthella bentotensis** (Castellani and Chalmers) Bergey et al. (*Bacterium bentotensis* Castellani, Cent. f. Bakt., I Abt., *65*, 1912, 262;

Bacterium bentotensis Weldin and Levine, Abs. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 227.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly. Motile possessing peritrichous flagella. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies.

Agar slant.

Broth: Turbid.

Litmus milk: Acid.

Potato: Dirty, gray, smooth, glistening.

Indol is formed.

Nitrates.

Acid but no gas in dextrose, levulose, galactose, maltose, lactose, sucrose, raffinose, salicin, glycerol, mannitol, dulcitol and inositol. No acid in arabinose, dextrin, inulin, mannitol or sorbitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

7. **Eberthella belfastiensis** (Weldin and Levine) Bergey et al. (*Bacillus belfastiensis II* Wilson, Jour. of Hygiene, *8*, 1908, 543; *Bacterium belfastiensis* Weldin and Levine, Abst. Bact., *7*, 1923, 13; Bergey et al., Manual, 1st ed., 1923, 226; *Bacillus coli anaerogenes* Kerrin, Jour. of Hyg., *28*, 1928, 4.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Circular, grayish-white, smooth.

Agar slant: Grayish-white streak.

Broth: Turbid.

Litmus milk: Acid; coagulated.

Potato: Brown growth.

Indol is formed.

Nitrates.

Acid but no gas in dextrose, levulose, arabinose, lactose, maltose, sucrose raffinose, dextrin, salicin, glycerol, glycol, mannitol, sorbitol and isodulcitol. No acid in dextrin, inulin, salicin or dulcitol.

Aerobic, facultative.

Optimum temperature.

Habitat: Intestinal canal in fever resembling typhoid.

8. **Eberthella pyogenes** (Migula) Bergey et al. (*Bacillus pyogenes foetidus* Passet, Fortschrit. der Med., 1885; *Bacterium pyogenes* Migula, Syst. der Bakterien, 1900, 381; *Lankoides pyogenes* Castellani and Chalmers, Manual of Tropical Medicine, 1919, 938; *Bacterium pyogenes foetidus* Holland, Jour. Bact., *5*, 1920, 215; Bergey et al., Manual, 1st ed., 1923, 226.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies: Grayish-white, raised, entire.

Gelatin stab: No liquefaction.

Agar colonies: Gray, smooth, entire.

Agar slant: Gray, plumose, smooth, glistening.

Broth: Turbid.

Litmus milk: Acid, coagulated.

Potato: Dirty-white, smooth, glistening.

Indol is formed.

Nitrates.

Acid but no gas in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, dextrin, raffinose, mannitol, dulcitol and sorbitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from rectal abscess.

9. **Eberthella oedematiens** Assis. (Boletin do Inst. Vital Brazil, *5*, 1928.)

Rods, straight or slightly curved, 0.3 to 0.4 by 1.5 to 3.0 microns, larger forms seen in older cultures. Motile. Gram-negative.

Gelatin colonies.

Gelatin stab: Liquefaction crateriform, becoming stratiform.

Agar colonies: Circular, glistening, transparent, undulate margin.

Agar slant: Grayish, coherent streak.

Broth: Turbid, grayish sediment, with pronounced odor.

Litmus milk: Acidification and coagulation. Peptonization.

Potato.

Indol is formed.

Nitrates are reduced to nitrites.

Acid in dextrose, levulose, galactose, arabinose, maltose, lactose, sucrose, dextrin, glycerol, mannitol and inositol.

Acetylmethylcarbinol not formed.

Agglutinins not absorbed from immune serum by typhoid bacilli.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal of man in dysentery suspects.

10. **Eberthella enterica** (Ford) Bergey et al. (*Bacillus entericus* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, No. 5, 1903, 40; Also see Jour. of Med. Research, *1*, 1901, 211; Bergey et al., Manual, 1st ed., 1923, 223.)

Rods: 0.5 by 1.5 to 3.0 microns, occurring singly, in pairs and long chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Small, circular, translucent, like "broken glass."

Gelatin stab: Rapid, stratiform liquefaction.

Agar colonies: White, with opaque center, slightly spreading.

Agar slant: White, glistening, spreading.
Broth: Markedly turbid.
Litmus milk: Acid, becoming alkaline.
Potato: Luxuriant, dirty-brown, spreading.
Indol is formed.
Nitrates reduced to nitrites.
Acid in dextrose, levulose, maltose, sucrose and dextrin.
Fecal odor rarely produced.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

11. **Eberthella dubia** (Chester) Bergey et al. (Meiner Bakterie, Bleisch, Zeitschr. f. Hyg., *13*, 1893, 31; *Bacillus dubius pneumoniae* Kruse in Flügge Die Mikroorganismen, *2*, 1896, 419; *Bacterium dubium* Chester, Manual of Determinative Bacteriology, 1901, 142; Bergey et al., Manual, 1st ed., 1923, 225.)

Rods: 0.75 by 2.0 microns, occurring singly, sometimes in pairs. Motile with peritrichous flagella. Gram-negative.
Gelatin colonies: Small, irregular, grayish-brown, slightly spreading.
Gelatin stab: Rapid liquefaction.
Agar colonies: Grayish, spreading, skin-like.
Agar slant: Abundant, yellowish, glistening, turning brown in old cultures.
Broth: Turbid.
Litmus milk: Acid with coagulation. Slow digestion.
Potato: Abundant, yellowish-brown, glistening, raised.
Slight amount of indol formed.
Nitrates reduced to nitrites.
Acid in dextrose.
Slight fecal odor produced.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

12. **Eberthella chylogena** (Ford) Bergey et al. (*Bacillus chylogenes* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, No. 5, 1903, 62; Bergey et al., Manual, 1st ed., 1923, 224.)

Rods: 0.5 by 1.0 micron, occurring singly and in pairs. Motile with peritrichous flagella. Gram-negative.
Gelatin colonies: Small, circular, grayish-white.
Gelatin stab: Liquefied.
Agar colonies: Very small, pale brown.
Agar slant: Pale, almost transparent film.
Broth: Turbid.
Litmus milk: Acid with coagulation.
Potato: Scanty white to pale yellow growth.

Indol not formed.
Nitrates not reduced.
Acid in dextrose.
No characteristic odor.
Aerobic, facultative.
Optimum temperature 37°C
Habitat: Intestinal canal.

13. **Eberthella xenopa** Schrire. (Schrire, Trans. Royal Soc. So. Africa, *17*, 1928, 43.)
Small rod: Motile. Gram-negative.
Gelatin colonies.
Gelatin stab: Crateriform liquefaction.
Agar colonies: Small, circular, white, entire.
Agar slant: Filiform, white, smooth, glistening.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: White, moist, glistening.
Indol not formed.
Nitrates not reduced.
Acid in dextrose and xylose.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Associated with wound infection in frogs.

Genus XXIII. Shigella *Castellani and Chalmers, 1919.*

Non-motile rods generally occurring in the intestinal canal of man in dysenteric states. Attack a number of carbohydrates with the formation of acid but no gas. Do not produce acetylmethylcarbinol.

The type species is *Shigella dysenteriae* (Shiga) Castellani and Chalmers.

Key to the species of genus Shigella.

1. No acid formed in mannitol.
  a. No acid formed in lactose.
  b. No acid formed in sucrose.
  c. Nitrates not reduced.
  d. Indol not formed.
    1. *Shigella dysenteriae.*
  dd. Indol is formed.
    2. *Shigella septicaemiae.*
    3. *Shigella ambigua.*
  cc. Nitrates reduced.
    4. *Shigella minutissima.*
aa. Acid formed in lactose.
  b. No acid formed in sucrose.
  c. Growth on potato barely visible.

5. *Shigella bienstockii.*

cc. Growth on potato yellowish-white.

6. *Shigella oxygenes.*

2. Acid formed in mannitol.
   a. No acid formed in lactose.
   b. No acid formed in xylose.

7. *Shigella paradysenteriae.*

bb. Acid formed in xylose.
   c. Acid formed in dulcitol.
   d. Acid formed in dextrin.

8. *Shigella jeffersonii.*

dd. No acid formed in dextrin.

9. *Shigella alkalescens.*

cc. No acid formed in dulcitol.

10. *Shigella pfaffi.*
11. *Shigella rettgeri.*

aa. Acid formed in lactose.
   b. Acid formed in salicin.

12. *Shigella equirulis.*

bb. No acid formed in salicin.

13. *Shigella dispar.*

1. **Shigella dysenteriae** (Shiga) Castellani and Chalmers. (Bacillus of Japanese dysentery, Shiga, Cent. f. Bakt., I Abt., *23*, 1898, 599; *Bacillus dysenteriae* Shiga, Cent. f. Bakt., I Abt., *24*, 1898, 817; *Bacillus shigae* Chester, Determinative Bacteriology, 1901, 228; *Bacillus dysentericus* Ruffer and Willmore, Brit. Med. Jour., *2*, 1909, 862; *Bacterium dysenteriae* Lehmann and Newmann, Bakt. Diag., 5th ed., 1912, 348; Not *Bacterium dysenteriae* Chester, Manual of Determ. Bact., 1901, 145; Castellani and Chalmers, A Manual of Tropical Medicine, 1919, 935; *Eberthella dysenteriae* Bergey, et al., Manual 2nd ed., 1925, 250.)

Rods: 0.4 to 0.6 by 1.0 to 3.0 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, grayish, smooth, homogeneous, entire to slightly undulate.

Gelatin stab: Grayish surface growth. No liquefaction.

Agar slant: Grayish, filiform to echinulate, smooth, entire to undulate.

Broth: Slightly turbid, with grayish sediment.

Litmus milk: Slightly acid, then alkaline.

Potato: Delicate, grayish to slightly brownish streak.

Indol not produced.

Nitrates not reduced.

Acid but no gas in dextrose, levulose, raffinose, dextrin, glycerol and adonitol. Does not attack arabinose, xylose, rhamnose, maltose, lactose, sucrose, dextrin, salicin, mannitol, dulcitol or isodulcitol.

Aerobic, facultative.

Optimum temperature 37°C.
Habitat: The cause of dysentery in man.

2. **Shigella septicaemiae** (Bergey et al.) Bergey et al. (*Bacillus septicaemiae anserum exudativae* Riemer, Cent. f. Bakt., I Abt., Orig., *37*, 1904, 648; *Eberthella septicaemiae* Bergey et al., Manual, 2nd ed., 1925, 250; Bergey et al., Manual, 3rd. ed., 1930, 358.)

Small rods: 0.1 by 0.3 to 1.0 micron, occurring singly, in pairs and in threads. Non-motile. Gram-negative.

Gelatin colonies: Small, white, circular.

Gelatin stab: Slight, infundibuliform liquefaction, becoming complete in several weeks.

Agar colonies: Circular, transparent, smooth, homogeneous, entire.

Agar slant: Soft, grayish-white streak, slightly viscid, becoming transparent.

Broth: Slight, uniform turbidity, with slight pellicle formation.

Litmus milk: Unchanged.

Potato: No growth.

Blood serum: Yellowish-white streak, the medium becoming brownish and slowly liquefied.

Indol is formed after several days.

Nitrates not reduced.

Acid is formed in dextrose.

H_2S is formed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Cause of a fatal septicemia in young geese. Not pathogenic for mice, guinea pigs, rabbits, chickens or pigeons.

3. **Shigella ambigua** (Andrewes) Weldin. (Bazillus Schmitz, Schmitz, Zeit. f. Hyg., *84*, 1917, 449, *Bacillus ambiguus* Andrews, The Lancet, *194*, 1918, 560; *Bacillus dysenteriae* "Schmitz" Murray, Jour. Roy. Army Med. Corps, *31*, 1918, 257; *Bacterium ambiguum* Levine, Abs. Bact., *4*, 1920, 15; *Eberthella ambigua* Bergey et al., Manual, 1st. ed., 1923, 229; *Bacillus paradysenteriae X* Stutzer, Cent. f. Bakt., I Abt., Orig., *90*,1923, 12; *Bacterium schmitzii* Weldin and Levine, Abs. Bact., *7*, 1923, 13; Weldin, Iowa State College Jour. Sci., *1*, 1927, 177; not *Bacterium ambiguum* Chester, Delaware College Ag. Ex. Station Ann. Rep., 1900, 59.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly and in pairs. Non-motile: Gram-negative.

Gelatin stab: Not liquefied.

Agar colonies.

Agar slant.

Broth: Turbid.

Litmus milk: Slightly acid at first, becoming neutral to slightly alkaline.

Potato.

Indol is formed.

Nitrates.

Acid in dextrose, rhamnose, and isodulcitol. Does not attack xylose, maltose, lactose, sucrose, dextrin, glycerol, mannitol or dulcitol.

Not pathogenic.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal. Not agglutinated by Shiga immune serum.

4. **Shigella minutissima** (Migula) Bergey et al. (*Bacterium pyogenes minutissimum* Kruse, in Flügge, Die Mikroorganism, *2*, 1896, 447; *Bacterium minutissimum* Migula, System der Bakterien, 1900, 418; *Eberthella minutissima* Bergey et al., Manual, 1st ed., 1923, 228; Bergey et al., Manual, 3rd ed., 1930, 359.)

Rods: 0.5 by 1.0 micron, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Small, circular, pale yellowish-brown, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular or oval, pale grayish, entire.

Agar slant: Thin film, transparent.

Broth: Slightly turbid.

Litmus milk: Acid, with coagulation.

Potato: Faint, white, glistening growth.

Indol not formed.

Nitrates reduced to nitrites.

Acid in dextrose.

No characteristic odor.

Aerobic, facultative.

Optimum temperatüre 37°C.

Habitat: Intestinal canal. Isolated from brain abscess by Kruse

5. **Shigella bienstockii** (Schroeter) Bergey et al. (Bacillus III, Bienstock, Zeitschr. f. Klin. Med., *8*, 1884; *Bacillus coprogenes parvus* Flügge, Die Mikroorganismen, 1886, 269; *Bacterium bienstockii* Schroeter, Kryptogamen Flora v. Schlesien, *3*, 1, 1886, 163; *Eberthella bienstockii* Bergey et al., Manual, 1st ed., 1923, 227; Bergey et al., Manual, 3rd ed., 1930, 360.)

Short rods: 0.5 by 0.7 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, pale, brown, entire.

Gelatin stab: Slow growth. No liquefaction.

Agar colonies: Small, circular, brown.

Agar slant: Filiform, grayish streak.

Broth: Turbid.

Litmus milk: Acid; slow coagulation. No digestion.

Potato: Grayish white, barely perceptible.

Indol not formed.

Nitrates not reduced.

Acid in dextrose and lactose.

No characteristic odor.

Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

6. **Shigella oxygenes** (Ford) Bergey et al. (*Bacterium oxygenes* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, No. 5, 1903, 47; *Eberthella oxygenes* Bergey et al., Manual, 1st ed., 1923, 228; Bergey et al., Manual, 3rd ed., 1930, 360.)

Rods: 0.5 by 2.0 to 3.0 microns, occurring singly. Non-motile. Gram-negative.
Gelatin colonies: Irregular, brownish, variable in size and shape.
Gelatin stab: Slight growth in stab. No liquefaction.
Agar colonies: Large, circular, bluish, translucent, spreading.
Agar slant: Thick, white glistening, echinulate.
Broth: Turbid.
Litmus milk: Acid, with coagulation.
Potato: Abundant, yellowish-white to yellowish-brown.
Indol not formed.
Nitrates not reduced.
Acid in dextrose and lactose.
No characteristic odor.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal.

7. **Shigella paradysenteriae** (Collins) Weldin. (*Bacillus dysenteriae* Flexner, Phil. Med. Jour., *6*, 1900, 414; *Bacillus dysenteriae* Hiss and Russell, Medical News, *82*, 1903, 289; *Bacillus dysenteriae* Strong, Jour. of Amer. Med. Assoc., *35*, 1906, 498; *Bacillus paradysenteriae* Collins, Jour. of Infec. Dis., *2*, 1905, 620; Includes weakly toxic strains of dysentery bacilli, Groups I and II, Sonne, Cent. f. Bakt., I Abt., Orig., *75*, 1915, 408; *Shigella flexneri* Castellani and Chalmers, A Manual of Tropical Medicine, 1919, 937; *Shigella dysenteriae* (Hiss and Russell, and Strong types) Castellani and Chalmers, ibid., 937; Not *Shigella paradysenteriae* Castellani and Chalmers, ibid., 937; *Bacillus flexneri* Levine, Jour. Infec. Dis., *27*, 1920, 31; *Bacterium flexneri* Levine, Abs. Bact., *4*, 1920, 15; *Bacterium dysenteriae* (Flexner type) and *Bacterium paradysenteriae*, Holland, Jour. Bac., *5*, 1920, 215; *Eberthella flexneri* Weldin and Levine, Abs. Bact., 7, 1923, 13; *Eberthella paradysenteriae* Bergey et al., Manual, 1st ed., 1923, 230; Weldin, Iowa State College Jour. Sci., *1*, 1927, 178.)

Morphologically the organisms are like *Shigella dysenteriae*.

Culturally they differ from *S. dysenteriae* in that they ferment dextrose galactose, maltose, arabinose, raffinose and mannitol. Some strains also ferment sucrose. No acid is produced from lactose or xylose.

Serologically they can be differentiated from *Shigella dysenteriae* by the agglutination and agglutinin absorption tests. They can also be differentiated from each other by the agglutination and the agglutinin absorption tests with specific antisera.

Three varieties of *Shigella paradysenteriae* are generally recognized, namely the Hiss and Russell, the Flexner and the Strong. A fourth more distinct variety, Sonne Group III, is described below. These can be differentiated by variation in the fermentation of maltose and sucrose, as indicated in the following:

	Dextrose	*Mannitol*	*Maltose*	*Sucrose*	*Indol*
Shigella dysenteriae (Shiga).....	+	−	−	−	−
Hiss and Russell variety.......	+	+	−	−	+
Flexner variety................	+	+	+	−	+
Strong variety	+	+	−	+	+
Sonne, Group III..............	+	+	+	+	−

Aerobic, facultative.
Optimum temperature 37°C.
Habitat: The cause of dysentery in man especially of the so-called "Summer diarrhoea," of infants.

A. **Shigella paradysenteriae** var. **sonnei** (Dysenterie bacillen, Group III, Sonne, Cent. f. Bakt., I Abt., Orig., *75*, 1915, 408; *Bacterium sonnei* Levine, Jour. Infec. Dis., *27*, 1920, 31; *Shigella sonnei* Weldin, Iowa State Coll., Jour. Sci., *1*, 1927, 182; *Bacillus dysenteriae* (Sonne type III), Kerrin, Jour. Hyg., *28*, 1928, 4.)
Rods: Non-motile. Gram-negative.
Gelatin stab: No liquefaction.
Colony formation: Conradi-Dirgalski medium-blue; Endo medium-colorless.
Agar slant: Grayish-white, smooth, glistening.
Broth: Turbid.
Litmus milk: Acid, becoming neutral and later becoming acid again.
Potato: Abundant, moist, yellowish-gray, spreading.
Indol not formed.
Nitrates.
Acid in dextrose, levulose, galactose, mannose, arabinose, raffinose, maltose, lactose, sucrose, dextrin, glycerol, mannitol and isodulcitol.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Sporadic cases of dysentery.

Note: The term *Bacillus paradysenteriae* is used by Kruse (Münch. med. Wchnsch. 1917, 1309) for the *Escherichia coli*-like motile and gas forming Gram-negative rods that have been found to cause dysentery-like diseases. See *Escherichia pseudodysenteriae* Bergey et al., p. 347. Kruse (Deut. Med. Wchnschr., *27*, 1901, 388), uses the term pseudo-dysentery for the group that includes the Flexner, Strong, and Hiss and Russell types. See Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 456. Gardner (System of Bacteriology, *4*, 1929, 170, Med. Res. Council, London) states that "Kruse's terms *B. dysenteriae* for Shiga, and *Bacillus pseudodysenteriae* for the Flexner-Sonne-Schmitz groups, have, however, never taken root outside the German-speaking world."

8. **Shigella jeffersonii** (Hadley et al.) Bergey et al. (*Bacterium jeffersonii* Hadley, Elkins and Caldwell, R. I. Agr. Exp. Sta., Bull. 174, 1918, 169; *Eberthella jeffersonii* Bergey et al., Manual, 1st ed., 1923, 230; Bergey et al., Manual, 3rd ed., 1930, 361.)

Rods: 0.5 by 0.8 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, gray, translucent, entire.

Gelatin stab: No liquefaction.

Agar colonies: Small, gray, smooth, translucent, entire.

Agar slant: Grayish, filiform, translucent.

Broth: Turbid, with flocculent sediment.

Litmus milk: Slightly acid. Slowly becoming alkaline.

Potato: Luxuriant, grayish growth.

Indol not formed.

Nitrates not reduced.

Acid in dextrose, levulose, galactose, mannose, arabinose, xylose, maltose, dextrin, mannitol and dulcitol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: In typhoid-like disease in poultry. Infectious for rabbits and pigeons.

9. **Shigella alkalescens** (Andrewes) Weldin. (*Bacillus alkalescens* Andrewes, The Lancet, London, *194*, 1918, 560; *Bacterium alkalescens* Levine, Jour. Infec. Dis., *27*, 1920, 31; *Eberthella alkalescens* Bergey et al., Manual, 1st ed., 1923, 231; Weldin, Iowa State College Jour. Sci., *1*, 1927, 179.)

Rods: 0.5 by 1.0 to 1.5 microns, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies.

Agar slant: Abundant, transparent, often iridescent.

Broth: Turbid.

Litmus milk: Alkaline.

Potato: Moderate, grayish growth.

Indol is formed.

Nitrates.

Acid but no gas in dextrose, xylose, rhamnose, maltose, mannitol, dulcitol and isodulcitol. Sucrose is fermented by some strains. Does not attack lactose, dextrin or salicin.

Aerobic, facultative.

Optimum temperature 37°C.

Not pathogenic.

Habitat: Intestinal canal. Not agglutinated by Shiga immune serum

10. **Shigella pfaffii** (Hadley et al.) Weldin. (*Bacterium pfaffi* Hadley, Elkins and Caldwell, R. I. Agr. Exp. Sta., Bull. No. 174, 1918, 169; *Eberthella pfaffi* Bergey et al., Manual, 1st ed., 1923, 232; Weldin, Iowa State College Jour. Sci., *1*, 1927, 180.)

Rods: 0.4 by 1.4 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, grayish, translucent.

Gelatin stab: No liquefaction.

Agar colonies: Small, grayish, homogeneous, translucent, entire.

Agar slant: Slight, grayish, translucent streak.

Broth: Turbid, with thin pellicle and flocculent sediment.

Litmus milk: Unchanged.

Potato: Moderate, whitish streak.

Acid but no gas in dextrose, levulose, arabinose, xylose, maltose, dextrin, salicin and mannitol. Does not attack lactose, sucrose or dulcitol.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Fowl typhoid. First encountered in an epidemic of septicemia in canaries.

11. **Shigella rettgeri** (Hadley et al.) Weldin. (*Bacterium rettgeri* Hadley, Elkins and Caldwell, R. I. Agr. Exp. Sta., Bull. No. 174, 1918, 169; *Eberthella rettgeri* Bergey et al., Manual, 1st ed., 1923, 232; Weldin, Iowa State College Jour. Sci., *1*, 1927, 181.)

Rods: 0.5 to 0.8 micron long, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Small, grayish, translucent, entire.

Gelatin stab: No liquefaction.

Agar colonies: Small, grayish, homogeneous, translucent, entire.

Agar slant: Filiform, grayish, translucent.

Broth: Turbid with flocculent sediment.

Litmus milk: Alkaline in eight days, becoming translucent.

Potato: Luxuriant, grayish growth.

Acid but no gas in dextrose, levulose, galactose, mannose, xylose, salicin, mannitol and adonitol. Does not attack arabinose, maltose, lactose, sucrose, dextrin or dulcitol.

Indol not formed.

Nitrates not reduced.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Fowl typhoid and some cholera-like diseases of birds.

12. **Shigella equirulis** (v. Straaten) Edwards. (*Bacillus nephritidis equi* Meyer, Transvaal Dept. Agr. Rpt. Gov. Bac., 1908–09, 122; *Bacillus equirulis* v. Straaten, Verslag van de Werksaamheden der Rijksseruminrichting, 1916–17; *Bacterium viscosum equi* Magnusson, Svensk. Veterinärtijdskr, 1917, 81; *Bacterium pyosepticus equi* de Blieck u. van Heelsbergen, Tydschr. v. Diergeneesk, *46*, 1919, 492; *Bacterium pyosepticum viscosum* Meissner, Deut. tierärtzl. Wchnschr., *29*, 1921, 185; *Bacterium pyosepticum*

Meissner, Deut. tierärtzl. Wchnschr. *31*, 1923, 348; *Bacterium pyosepticum equi* Landien, Inaug. Diss., Hannover, 1923; *Bacillus pyosepticus* Clarenberg, Ztschr. f. Infekkr. u. Hyg. d. Haust., *27*, 1924, 193; *Bacterium equi* Weldin and Levine, Abs. Bact., *7*, 1923, 13; *Eberthella viscosa* Snyder, Jour. Am. Vet. Med. Assoc., *66*, 1925, 481; *Shigella equi* Weldin, Iowa State Col. Jour. Sci., *1*, 1927, 121; *Shigella viscosa* Bergey et al., Manual 3rd ed., 1930, 363; Edwards, Kentucky Agr. Exp. Sta., Res. Bul., 320.)

Rods with rounded ends, 0.3 to 0.4 by 0.4 to 0.8 micron, occurring singly and in pairs. Non-motile. Gram-negative.

Gelatin colonies: Grayish-white, circular, translucent.

Gelatin stab: Moderate growth along line of stab. No liquefaction.

Agar colonies: Semi-solid, tough, ropy, adherent, circular, grayish-white, hemispherical, smooth, moist, glistening.

Agar slant: Grayish-white, viscid, covering the surface.

Broth: Grayish, tough, ropy sediment. At times, a thin, grayish pellicle is observed.

Litmus milk: Slowly acidified; slimy, viscid.

Potato: No visible growth.

Indol not formed.

Nitrates.

Acid but no gas in dextrose, levulose, xylose, lactose, maltose, sucrose, mannitol and salicin. No action in rhamnose, arabinose, dextrin, dulcitol, isodulcitol, sorbitol or inositol.

Optimum temperature 37°C.

Aerobic, facultative.

Pathogenesis. Non-pathogenic for small experimental animals. Produces abscess and stiffening of the joints when injected subcutaneously in horses.

Habitat: Cause of "joint-ill" in foals.

13. **Shigella dispar** (Andrewes) Bergey et al. (*Bacillus dispar* Andrewes, The Lancet, London, *194*, 1918, 560; *Bacterium dispar*, Levine, Abs. Bact., *4*, 1920, 15; *Eberthella dispar* Bergey et al., Manual, 1st ed., 1923, 364; Bergey et al., Manual, 3rd ed., 1930, 364.)

Note: According to Weldin, Iowa State Coll., Jour. Sci., *1*, 1927, 181 this species also includes *Bacillus madampensis* and *Bacillus ceylonensis B* Castellani, Cent. f. Bact., I Abt., Orig., *65*, 1912, 268.

Rods: 0.5 by 1.0 to 1.5 microns, with rounded ends, occurring singly. Non-motile. Gram-negative.

Gelatin colonies.

Gelatin stab.

Agar colonies.

Agar slant.

Broth.

Litmus milk: Acid, coagulated.

Potato.

Indol shows slight reaction with some strains.

Nitrates.

Acid in dextrose, maltose, lactose and mannitol. Several strains have been found to form acid in sucrose, xylose and dulcitol.

Pathogenic for rabbits.

Not agglutinated by Shiga immune serum.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

Genus XXIV. Brucella *Meyer and Shaw, 1920.*

Minute rods with many coccoid cells, 0.5 by 0.5 to 2 microns, non-motile, Gram negative; preferring a slightly reduced or partial pressure of oxygen; gelatin not liquefied; neither acid nor gas from carbohydrates; parasitic, invading animal tissue, producing infection of the genital tract, the mammary gland or the lymphatic tissues and the intestinal tract.

The type species is *Brucella melitensis* (Bruce) Meyer and Shaw.

A. Grow in media containing basic fuchsin.
  1. Grow in media containing thionin.
    1. *Brucella melitensis.*
  2. Do not grow in media containing thionin.
    2. *Brucella abortus.*

AA. Do not grow in media containing basic fuchsin.
  1. Grow in media containing thionin.
    3. *Brucella suis.*

Differential characters of species of genus Brucella

Species	Infectivity for guinea pigs	CO_2 tolerance	H. S. formation	Dextrose utilized	Amino-nitrogen utilized	Effect of dyes	
						Thionin	Basic fuchsin
		10 per cent	*days*				
Brucella melitensis	++	+	0	+++	+	+++	+++
Brucella abortus	+	++	2	+	++	+	+++
Brucella suis	++	+	4	+++	+	+++	+

1. **Brucella melitensis** (Bruce) Meyer and Shaw. (Practitioner, *39*, 1887, 161; *ibid*, *40*, 1888, 241; Rept. Army Med. Dept., London, *32*, 1890, Append. No. 4, 465; *Micrococcus melitensis* Bruce, Ann. de l'Institut Pasteur, *7*, 1893, 289; *Bacterium melitensis* Evans, Jour. Infec. Dis., *22*, 1918, 581; Meyer and Shaw, Jour. Infect. Dis., *27*, 1920, 173; *Bacillus melitensis* Khaled, Jour. Hyg., *20*, 1921, 319; *Alcaligenes melitensis* Bergey et al., Manual, 1923, 235.)

Short oval rods: 0.3 to 0.4 microns in length, occurring singly and in pairs, rarely in short chains. Non-motile, Gram negative.

Gelatin colonies: Small, clear, entire.

Gelatin stab: Slow growth. No liquefaction.

Agar colonies: "Ground glass" appearance, small, circular, convex, with dark center.

Agar slant: Slow development as pearly gray colonies, rosette form.

Broth: Turbid, with heavy grayish sediment.

Litmus milk: Unchanged or slightly alkaline.

Potato: Scant growth, grayish becoming brownish.

Indol not formed.

Nitrates not reduced.

No acid or gas in carbohydrate media.

Urea reduced to ammonia.

Microaerophilic.

Optimum temperature 37°C.

Habitat: The cause of undulant fever in man (Malta fever). Distributed, as a rule, through goat's milk. The cause of abortion in goats.

2. **Brucella abortus** (Schmidt and Weis) Meyer and Shaw. (Bacillus of abortion, Bang. Zeitschr. f. Thiermed. *1*, 1897, 241; *Bacterium abortus* Schmidt and Weis, Bakterierne, 1901, 266; *Bacillus abortus* Evans, Jour. Wash. Acad. Sci. *5*, 1915, 122; *Alcaligenes abortus* Bergey et al., Manual, 1st ed., 1923, 234; Meyer and Shaw, Jour. Infec. Dis., *27*, 1920, 173.)

Rods: 0.4 to 0.5 by 0.6 to 1.5 microns, occurring singly. Non-motile, Gram negative.

Gelatin stab: No liquefaction.

Agar colonies: Very small, transparent.

Agar slant: Opalescent, lustrous, moist, entire.

Broth (alkaline): Slight turbidity.

Litmus milk: Slightly alkaline.

Potato: Slight, glistening, brownish growth. Medium assumes a brownish tinge.

Indol not formed.

Nitrates not reduced.

Urea and asparagin reduced to ammonia.

No acid or gas in carbohydrate media.

Microaerophilic.

Optimum temperature 37°C.

Habitat: The cause of contagious abortion in cattle. The same effects are produced in mares, sheep, rabbits and guinea pigs. Causes undulant fever in man.

3. **Brucella suis** Huddleson. (Tech. Bul. No. 100, Mich. Agr. Exp. Sta., 1929, 12.)

The morphologic and cultural characters are similar to those of *Brucella melitensis* and *Brucella abortus*.

Comparative studies of *Brucella melitensis*, *Brucella abortus* and *Brucella suis*, have emphasized the need for differential tests. *Brucella abortus* requires higher percentages of CO_2 in order to grow than the other species. *Brucella abortus* also possesses a lower power of utilizing dextrose in media than the other species. *Brucella abortus* is also inhibited in growth by concentrations of thionin in culture media, which do not inhibit the growth of the other species. Basic fuchsin inhibits the growth of *Brucella abortus* in concentrations which do not inhibit the growth of the other species. The organisms that grow on thionin medium, but not on basic fuchsin medium, are *Brucella suis*.

Brucella melitensis can be differentiated from *Brucella abortus* by the agglutination absorption test. The R type of *Brucella suis* can be differentiated from *Brucella abortus* by the agglutinin absorption test, provided this type is used as antigen.

Microaerophilic. Optimum temperature 37°C.

Habitat: Causes abortion in swine. Frequently causes undulant fever in man. Also infectious for the horse and dog.

Genus XXV. Alcaligenes *Castellani and Chalmers, 1918.*

Motile or non-motile rods, generally occurring in the intestinal canal of normal animals. Do not form acetylmethylcarbinol. Do not ferment any of the carbohydrates.

The type species is *Alcaligenes faecalis* Castellani and Chalmers.

Key to the species of genus Alcaligenes.

A. Gelatin not liquefied.
  a. Motile.
    1. *Alcaligenes faecalis.*
    2. *Alcaligenes bronchisepticus.*
  aa. Non-motile.
  b. Ammonia not formed.
  c. Produces ropy milk.
    3. *Alcaligenes viscosus.*
  cc. Does not produce ropy milk.
    4. *Alcaligenes metalcaligenes.*
  bb. Ammonia is formed.
    5. *Alcaligenes ammoniagenes.*
    6. *Alcaligenes denieri.*

AA. Gelatin liquefied.
  a. Motile.
  b. Liquefaction saccate.
  c. Milk peptonized.
    7. *Alcaligenes bookeri.*
  cc. Milk not peptonized.
    8. *Alcaligenes recti.*
  aa. Non-motile.
  b. Liquefaction infundibuliform.

9. *Alcaligenes marshallii.*

bb. Liquefaction napiform to stratiform.

10. *Alcaligenes albus.*

1. **Alcaligenes faecalis** Castellani and Chalmers. (*Bacillus faecalis alcaligenes* Petruschky, Cent. f. Bakt., I Abt., *19*, 1896, 187; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 936.)

Rods: 0.5 by 1.0 to 2.0 microns, occurring singly and in pairs and occasionally in long chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, grayish, translucent.

Gelatin stab: Gray surface growth. No liquefaction.

Agar colonies: Transparent with opaque center, undulate margin.

Agar slant: White, glistening, opalescent, undulate margin.

Broth: Turbid, with thin pellicle, and viscid sediment. Gives off ammonia.

Litmus milk: Alkaline.

Potato: Scanty to abundant, yellowish to brownish.

Indol not formed.

Nitrates not reduced.

No acid or gas in carbohydrate media.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal. Found in endocarditis but generally considered non-pathogenic.

Note: Evans (Public Health Rpts., *46*, 1931, 1676) describes a gelatin liquefying strain of the species, *Alcaligenes faecalis* var. *radicans*.

2. **Alcaligenes bronchisepticus** (Ferry) Bergey et al. (*Bacillus bronchisepticus* Ferry, Amer. Vet. Rev., April, 1912; Bergey et al., Manual, 1st ed., 1923, 234.)

Short slender rods, 0.4 to 0.5 by 2.0 microns, occurring singly. Motile, possessing peritrichous flagella. Gram-negative.

Gelatin colonies.

Gelatin stab: No liquefaction.

Agar colonies: Small, opaque, white, slightly raised, porcellaineous, entire.

Agar slant: Opalescent, lustrous, moist, entire.

Broth: Distinctly turbid, with thin, gray pellicle and ropy sediment.

Litmus milk: Alkaline.

Potato: Fairly abundant, brownish, glistening.

Indol not formed.

Nitrates not reduced.

No acid or gas in carbohydrate media.

Ammonia formed from urea and asparagin.

Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Believed to be the cause of distemper in dogs. It also causes acute infection in cats, rabbits, guinea pigs, ferrets, white rats, and monkeys.

3. **Alcaligenes viscosus** (Bergey et al.) Weldin. (*Bacillus lactis viscosus* Adametz, Cent. f. Bakt., *9*, 1891, 698; *Bacillus viscosus lactis* Kruse, in Flügge, Die Mikroorganismen, 1896, 359; *Bacterium viscosus lactis* Chester, Delaware Agr. Exp. Sta. 9th Ann. Rept., 1897, 128; *Bacterium lactis viscosum* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1898 (Eng. ed., 1901, 196); Group I varieties 1, 2, 3, 4 and 5 of Harrison, Rev. Gén. du Lait, *5*, 1905, 100; *Bacterium visco-coccoidium* Buchanan and Hammer, Iowa Agr. Exp. Stat., Research Bull. 22, 1915, 260; *Lactobacillus viscosus* Bergey et al., Manual, 1st ed., 1923, 244; *Achromobacter viscosum* Bergey et al., Manual, 2nd ed., 1925, 169; Weldin, Iowa State College Jour. Sci., *1*, 1927, 186.)
Rods: 0.5 to 1.2 by 0.5 to 2.5 microns, occurring singly, in pairs or short chains. Non-motile. Gram-negative. Capsules in milk.
Gelatin colonies: Small, gray becoming yellowish.
Gelatin stab: White surface growth with villous growth in stab. No liquefaction.
Agar colonies: Small, flat, becoming raised, brownish.
Agar slant: Dirty white, opalescent, luxuriant.
Broth: Slightly turbid, with white tenaceous sediment.
Litmus milk: Slimy to ropy, alkaline after a month.
Potato: Abundant, drab, tenaceous, slimy.
Indol not formed.
Nitrates not reduced.
No action on sugars.
Aerobic, facultative.
Optimum temperature 25°C.
Habitat: Ropy milk.

4. **Alcaligenes metalcaligenes** Castellani and Chalmers. (Manual of Tropical Medicine, 1919, 936; *Bacterium metalcaligenes* Weldin and Levine, Abs. Bact., *7*, 1923, 13; *Achromobacter metalcaligenes* Bergey et al., Manual, 2nd ed., 1925, 169.)
Rods: 0.6 by 1.5 microns, with rounded ends, occurring singly and in pairs. Non-motile. Gram-negative.
Gelatin stab: No liquefaction.
Agar colonies: Circular, raised, smooth, amorphous, entire, gray.
Agar slant: Gray, scanty, filiform, contoured, viscid.
Broth: Membranous pellicle with heavy sediment.
Litmus milk: Alkaline.
Potato: Scanty, glistening, smooth, faint pink.
Indol not formed.
Nitrate reduction variable.

Starch not hydrolyzed.
Blood serum not liquefied.
No action on carbohydrates.
Aerobic, facultative.
Optimum temperature 22°C.
Habitat: Intestinal canal.

5. **Alcaligenes ammoniagenes** (Cooke and Keith) Bergey et al. (*Bacterium ammoniagenes* Cooke and Keith, Jour. of Bact., *13*, 1927, 315; Bergey et al., Manual, 3rd ed., 1930, 367.)

Rods with rounded ends, 0.8 by 1.4 to 1.7 microns, occurring singly. Non-motile. Gram-negative.
Gelatin stab: No liquefaction.
Agar colonies: Circular, flat, smooth, entire, gray.
Agar slant: Moderate, smooth, flat, opaque, glistening, butyrous, amorphous.
Broth: Moderate turbidity, with flocculent sediment.
Litmus milk: Slightly alkaline.
Indol not formed.
No action on carbohydrates.
Blood serum not liquefied.
Urea is fermented forming ammonia.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal tract of infants.

6. **Alcaligenes denieri** Corbet (Quart. Jour. Rubber Research Inst., Malaya, *2*, 1930, 152.)

Rods: 0.8 by 2.9 microns, with rounded ends, occurring singly. Non-motile. Gram-positive.
Gelatin stab: No liquefaction.
Agar slant: Moderate, filiform, colorless, flat, dull.
Broth: Slight sediment.
Litmus milk: Alkaline.
Indol is not formed.
Nitrates are not reduced.
No action on carbohydrates.
Traces of ammonia formed.
Aerobic.
Optimum temperature 30°C.
Habitat: Isolated from the latex of *Hevea brasiliensis*.

7. **Alcaligenes bookeri** (Ford) Bergey et al. (Bacillus A of Booker, Trans. Ninth Internat. Med. Congress, *3*, 1887, 598; *Bacillus bookeri* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, 1903, 31; Bergey et al., Manual, 1st ed., 1923, 236; *Bacterium bookeri* Levine and Soppeland, Eng. Exp. Sta., Iowa State Callege, Bul. 77, 1926, 55.)

Rods: 0.5 by 1.5 to 2.0 microns, occurring singly. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Circular, brown, variable in size.

Gelatin stab: Slow, saccate liquefaction, becoming stratiform.

Agar colonies: Thin, transparent, with opaque center and indistinct margin.

Agar slant: Abundant, yellowish to yellowish-brown.

Broth: Turbid, with viscid sediment.

Litmus milk: Alkaline. Soft curd. Litmus reduced. Peptonization.

Potato: Luxuriant, yellowish-white, moist. Medium is darkened.

Indol not formed.

Nitrates show slight reduction in 7 days.

No acid or gas in carbohydrate media.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

8. **Alcaligenes recti** (Ford) Bergey et al. (*Bacterium recti* Ford, Studies from the Royal Victoria Hospital, Montreal, *1*, 1903, 31; Bergey et al., Manual, 1st ed., 1923, 236.)

Rods: 0.5 by 1.5 to 2.0 microns, occurring singly, in pairs and in chains. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies: Variable in size and shape, circular to oval, brown.

Gelatin stab: Rapid, saccate liquefaction.

Agar colonies: Large, grayish-white, with opaque center. Slightly spreading.

Agar slant: Grayish-white, echinulate.

Broth: Turbid.

Litmus milk: Alkaline. No peptonization.

Potato: Luxuriant, moist, brownish-red.

Indol not formed.

Nitrates reduced to nitrites.

No acid or gas in carbohydrate media.

No characteristic odor.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Intestinal canal.

9. **Alcaligenes marshallii** Bergey et al. (Bacillus B of Marshall, Cent. f. Bakt., II Abt., *11*, 1903, 739; *Bacterium lactis marshalli*, Conn, Esten and Stocking, Ann. Rept. Storrs Agr. Exp. Station, 1906, 141.)

Rods: 0.3 by 1.2 microns, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Gray, granular, irregular, glistening.

Gelatin stab: Slow, infundibuliform liquefaction.

Agar slant: Filiform, gray to creamy-white, raised, becoming lemon-yellow.

Broth: Turbid, with gray ring and viscid sediment.
Litmus milk: Alkaline, slimy, peptonized.
Potato: Luxuriant, lemon-yellow, smooth.
Indol not formed.
Nitrates not reduced.
No acid or gas in carbohydrate media.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Milk.

10. **Alcaligenes albus** Bergey et al. (*Bacterium lactis album* Conn, Esten, Stocking, Annual Report, Storrs Agr. Exp. Station, 1906, 143; Bergey et al., Manual, 1st ed., 1923, 237.)

Rods: 0.7 to 0.9 by 1.0 to 3.0 microns, occurring singly. Non-motile. Gram-positive.
Gelatin colonies: Small, gray, entire.
Gelatin stab: Slow napiform to stratiform liquefaction.
Agar slant: Filiform, cream white, raised, smooth, luxuriant, viscous.
Broth: Turbid, with gray pellicle and sediment.
Litmus milk: Alkaline, peptonized.
Potato: Abundant, spreading, convex, smooth, brown. Medium discolored.
Indol not formed.
Nitrates not reduced.
No acid or gas in carbohydrate media.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Isolated from udder of cow.

TRIBE XIII. BACTEROIDEAE CASTELLANI AND CHALMERS, 1919.

Motile or non-motile rods, without endospores. Show good growth on ordinary culture media; without pigment formation. Obligate anaerobes.

Genus XXVI. Bacteroides *Castallani and Chalmers, 1919.*

The characters of the genus are those of the tribe.

The type species is *Bacteroides fragilis* (Veillon and Zuber) Castellani and Chalmers.

Key to the species of genus Bacteroides.

A. Non-motile.
   1. Milk unchanged.
      a. Slight acidity in dextrose.
      b. Indol is not formed.
      c. Gram-variable.
         1. *Bacteroides fragilis.*

aa. Acid and gas in dextrose.
b. Indol is formed.
c. Gram-negative.
2. *Bacteroides variabilis.*
bb. Indol is not formed.
c. Gram-positive.
3. *Bacteroides cornutus.*
cc. Gram-negative.
4. *Bacteroides fundibuliformis.*
2. Milk slightly acid; not coagulated.
a. Acid in dextrose.
b. Indol is not formed.
c. Gram-positive.
5. *Bacteroides oviformis.*
6. *Bacteroides bifidus.*
cc. Gram-negative.
7. *Bacteroides laevis.*
3. Milk acid; coagulated.
a. No action on dextrose.
b. Indol is not formed.
c. Gram-positive.
8. *Bacteroides dimorphus.*
aa. Acid in dextrose.
b. Indol is formed.
c. Gram-positive.
9. *Bacteroides pseudoramosus.*
10. *Bacteroides acuminatus.*
aaa. Acid and gas in dextrose.
b. Indol is formed.
c. Gram-positive.
11. *Bacteroides angulosus.*
4. Milk acid.
a. Acid and gas in dextrose.
b. Indol is not formed.
c. Gram-positive.
12. *Bacteroides tortuosus.*
AA. Motile.
1. Milk slightly acid; not coagulated.
a. Acid in dextrose.
b. Indol is not formed.
c. Gram-negative.
13. *Bacteroides bullosus.*
2. Milk acid; coagulated.
a. Acid in dextrose.
b. Indol is formed.
c. Gram-negative.
14. *Bacteroides varigatus.*

bb. Indol is not formed.

15. *Bacteroides thetaiotaomicron.*

3. Milk coagulated; peptonized.
   a. Acid in dextrose.
   b. Indol is formed.
   c. Gram-negative.

16. *Bacteroides liquefaciens.*
17. *Bacteroides tenuis.*

cc. Gram-positive.

18. *Bacteroides multiformis.*

bb. Indol is not formed.
   c. Gram-negative.

19. *Bacteroides rigidus.*

1. **Bacteroides fragilis** (Veillon and Zuber) Castellani and Chalmers. (*Bacillus fragilis* Veillon and Zuber, Arch. Med. Exp. et d. Anat. Path., *10*, 1898, 870; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 959.)

Rods with rounded ends, staining more deeply at the poles, occurring singly and in pairs. Non-motile. Gram-variable.

Gelatin stab: No liquefaction.
Agar colonies: Small, gray, irregular.
Agar slant.
Broth: Turbid.
Litmus milk: Unchanged.
Potato.
Indol not formed.
Nitrates not reduced.
Slight acidity in dextrose.
Anaerobic.
Optimum temperature 37°C.
Habitat: Isolated from a gangrenous appendix.

2. **Bacteroides variabilis** (Distaso) Castellani and Chalmers. (*Bacillus variabilis* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 441; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 960.)

Short rods, with rounded ends, occurring singly and in short chains. Non-motile. Gram-negative.

Gelatin colonies: No growth.
Gelatin stab: No liquefaction.
Dextrose agar colonies: Deep colonies, small spherical, translucent.
Dextrose agar slant.
Broth: Gray sediment.
Litmus milk: Unchanged.
Potato.
Indol is formed.
Nitrates not reduced.

Acid and gas in dextrose, lactose and sucrose.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

3. **Bacteroides cornutus** (Distaso) Castellani and Chalmers. (*Bacillus cornutus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 443; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 960.)
Small, slender rods, occurring singly and in pairs. Non-motile Gram-positive.
Gelatin colonies: No growth.
Gelatin stab: No liquefaction.
Dextrose agar colonies: Deep colonies, small, gray.
Dextrose agar slant.
Broth: Slight, gray sediment.
Litmus milk: Unchanged.
Potato.
Indol not formed.
Nitrates not reduced.
Slight amount of acid and gas in dextrose.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal (common). Resembles somewhat *Bacteroides bifidus*.

4. **Bacteroides fundibuliformis** (Hallé) Bergey et al. (*Bacillus fundibuliformis* Hallé, Inaug. Dissertation, Paris, 1898; Gohn and Sacks, Cent. f. Bakt., I Abt., Orig., *38*, 1905, 135; Bergey et al., Manual, 3rd ed., 1930, 373.)
Small, Gram-negative rods. Non-motile.
Gelatin not liquefied.
No growth on albumin-free media.
Litmus milk: No coagulation.
Blood serum: Slowly liquefied.
Indol not formed.
H_2S is formed.
Forms ethyl alcohol, lactic acid and acetic acid from dextrose.
Slight gas formation.
Very offensive odor of putrefaction.
Anaerobic.
Optimum temperature 37°C.
Habitat: Vaginal abscess.

5. **Bacteroides oviformis** (Tissier) Levine and Soppeland. (*Coccobacillus oviformis* Tissier, Ann. d'l'Institut Pasteur, *22*, 1908, 189; *Bacterium oviforme* Le Blaye and Guggenheim, Manual pratique de diagnostique bacteriologique, Paris, 1914; Levine and Soppeland, Iowa Engineering Ex. Sta., Bul. 77, 1926, 35.)

Slightly curved rods with rounded ends, 0.6 to 1.0 by 1.3 to 2.2 microns, occurring singly, in pairs and in short chains. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Circular, smooth, amorphous, entire.

Agar slant: Flat, filiform, smooth, glistening, butyrous.

Broth: Slight turbidity, with scant sediment.

Litmus milk: Slight acidity. No peptonization or coagulation.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Starch not hydrolyzed.

Acid in dextrose and sucrose.

Anaerobic.

Moderate growth at 22°C.

Habitat: Intestinal tract.

6. **Bacteroides bifidus** (Tissier) Castellani and Chalmers. (*Bacillus bifidus* Tissier, La flora intestinale des nourressores, Paris, 1900; Manual of Tropical Medicine, 1919, 960.)

Rods: 0.3 to 0.6 by 1.5 to 5.0 microns, occurring singly and showing bifurcations. Non-motile. Gram-positive.

Gelatin colonies.

Gelatin stab.

Agar colonies.

Agar slant.

Broth: Turbid, clearing.

Litmus milk: Acid. Not coagulated.

Potato.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, lactose, maltose, sucrose and raffinose, and usually in mannitol.

Anaerobic.

Optimum temperature 37°C.

Habitat: Intestinal canal.

7. **Bacteroides laevis** (Distaso) Bergey et al. (*Bacillus laevis* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 444; Bergey et al., Manual, 1st ed., 1923, 259.)

Very small, slender rods, occurring singly and in short chains. Non-motile. Gram-negative.

Gelatin stab: No liquefaction.

Dextrose agar colonies: Small, transparent.

Dextrose agar slant.

Broth.

Litmus milk: Slowly becoming acid. No coagulation.

Potato.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, lactose and sucrose.
Anaerobic.
Optimum temperature 37°C.
Habitat: Common in intestinal canal of man and mammals.

8. **Bacteroides dimorphus** Bergey et al. (*Bacillus dimorphus* var. *longa* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 440; Bergey et al., Manual, 1st ed., 1923, 258.)

Long rods, granular, occurring singly, in pairs and in chains. Non-motile. Gram-positive.
Gelatin colonies: Deep colonies filamentous.
Gelatin stab: No liquefaction.
Dextrose agar colonies: Deep colonies, porcelain white, with filamentous margin.
Dextrose agar slant.
Broth.
Litmus milk: Slightly acid; coagulated.
Potato.
Indol not formed.
Nitrates not reduced.
No acid in carbohydrate media.
Forms butyric acid in milk.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

9. **Bacteroides pseudoramosus** (Distaso) Bergey et al. (*Bacillus pseudoramosus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 441; Bergey et al., Manual, 1st ed., 1923, 259.)

Rods, with rounded ends, occurring singly and in short chains. Non-motile. Gram-positive.
Gelatin stab.
Dextrose agar colonies.
Dextrose agar slant.
Broth: Turbid, with gray sediment.
Litmus milk: Slightly acid. Slow coagulation.
Potato.
Indol is formed.
Nitrates.
Acid in dextrose, lactose and sucrose, giving slight odor of butyric acid.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal (common).

10. **Bacteroides acuminatus** (Distaso) Bergey et al. (*Diplobacillus acuminatus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 440; Bergey et al. Manual, 1st ed., 1923, 260.)

Short rods, with rounded ends, occurring singly and in pairs. Non-motile. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: No liquefaction.

Dextrose agar colonies: Small, irregular, translucent.

Dextrose agar slant: No growth.

Broth: Turbid.

Litmus milk: Acid; coagulated.

Potato.

Indol is formed.

Nitrates not reduced.

Acid in dextrose, lactose and sucrose, forming slight odor of butyric acid.

Anaerobic.

Optimum temperature 37°C.

Habitat: Intestinal canal (common).

11. **Bacteroides angulosus** (Distaso) Bergey et al. (*Bacillus angulosus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 442; Bergey et al., Manual, 1st ed., 1923, 260.)

Rods, with rounded ends, occurring singly and in pairs. Encapsulated. Non-motile. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: No liquefaction.

Dextrose agar colonies: Large, angular, opaque, yellowish.

Dextrose agar slant.

Broth: Turbid.

Litmus milk: Acid; coagulated in 14 days.

Potato.

Indol is formed.

Nitrates.

Acid and gas in dextrose, lactose and sucrose, forming butyric acid.

Anaerobic.

Optimum temperature 37°C.

Habitat: Intestinal canal.

12. **Bacteroides tortuosus** (Debono) Bergey et al. (*Bacillus tortuosus* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 233; Bergey et al., Manual, 1st ed., 1923, 259.)

Rods, with rounded ends, occurring singly and in long, tortuous chains. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Dextrose agar colonies: Deep colonies, small, gray, translucent.

Dextrose agar slant.

Broth: Turbid.

Litmus milk: Acid.
Potato.
Indol not formed.
Nitrates not reduced.
Acid and gas in dextrose, lactose and sucrose.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

13. **Bacteroides bullosus** (Distaso) Castellani and Chalmers. (*Bacillus bullosus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 443; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 960.)

Small rods, with rounded ends, showing bipolar staining. At times, long, slender, bifurcating forms are seen with an enlargement at one pole or in the center. Motile. Gram-negative.
Gelatin stab: No liquefaction.
Dextrose agar colonies: Deep colonies, very small, with fimbriate margin.
Dextrose agar slant.
Broth.
Litmus milk: Slight acidity. No coagulation.
Potato.
Indol not formed.
Nitrates not reduced.
Acid in dextrose.
Anaerobic.
Optimum temperature 37°C
Habitat: Intestinal canal.

14. **Bacteroides variegatus** (Distaso) Castellani and Chalmers. (*Bacillus variegatus* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 445; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 960.)

Rods, occurring singly and in chains. Motile. Gram-negative.
Gelatin stab: No liquefaction.
Dextrose agar colonies: Small, translucent, entire.
Dextrose agar slant.
Broth.
Litmus milk: Acid; coagulated.
Potato.
Indol formed.
Nitrates not reduced.
Acid formed in dextrose and lactose.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

15. **Bacteroides thetaiotaomicron** (Distaso) Castellani and Chalmers. (*Bacillus thetaiotaomicron* Distaso, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 444; Castellani and Chalmers, Manual of Tropical Medicine, 1919, 960.)

Short, plump rods, at times staining irregularly. Motile. Gram-negative.

Gelatin stab: No liquefaction.

Dextrose agar colonies: Large, transparent, entire.

Dextrose agar slant.

Broth: Turbid.

Litmus milk: Acid; coagulated.

Potato.

Indol not formed.

Acid formed in dextrose and lactose.

Anaerobic.

Habitat: Intestinal canal (common).

16. **Bacteroides liquefaciens** (Distaso) Bergey et al. (*Coccobacillus liquefaciens* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 102; Bergey et al., Manual, 1st ed., 1923, 262.)

Small, slender rods, occurring singly, with rounded ends. Motile. Gram-negative.

Gelatin stab: Liquefaction.

Dextrose agar colonies: Small, translucent.

Dextrose agar slant.

Broth.

Litmus milk: Acid; coagulation; peptonized.

Potato.

Indol is formed.

Nitrates.

Acid in dextrose, lactose and sucrose.

White of egg is slowly peptonized.

Anaerobic.

Optimum temperature 37°C.

Habitat: Intestinal canal.

17. **Bacteroides tenuis** Bergey et al. (*Bacillus tenuis spatuliformis* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 101; Bergey et al., Manual, 1st ed., 1923, 263.)

Slender rods, occurring singly and in pairs, occasionally slightly curved. Motile. Gram-negative.

Gelatin stab: Liquefied.

Dextrose agar colonies: Small, circular, translucent.

Dextrose agar slant.

Broth: Turbid, with gray sediment and black pigment.

Litmus milk: Coagulated; peptonized.

Potato.

Indol is formed. Skatol is formed.

Nitrates.
Acid in dextrose.
White of egg is peptonized.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

18. **Bacteroides multiformis** (Distaso) Bergey et al. (*Bacillus multiformis* Distaso, Cent. f. Bakt., Orig., *59*, 1911, 101; Bergey et al., Manual, 1st ed., 1923, 263.)

Large rods, occurring singly, in pairs or short chains, frequently slightly curved. Motile. Gram-positive.
Gelatin stab: Liquefied.
Dextrose agar colonies: Lenticular, opaque.
Dextrose agar slant.
Broth.
Litmus milk: Coagulated; peptonized.
Potato.
Indol formed in small quantity.
Nitrates.
Acid formed in dextrose and lactose. Cultures give off odor of valerianic acid.
White of egg is peptonized.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

19. **Bacteroides rigidus** (Distaso) Bergey et al. (*Bacillus rigidus* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 103; Bergey et al., Manual, 1st ed., 1923, 263.)

Slender rods, with rounded ends, occurring singly and in pairs. Motile. Gram-negative.
Gelatin stab: Liquefied.
Dextrose agar colonies.
Dextrose agar slant.
Broth.
Litmus milk: Coagulated; peptonized.
Potato.
Indol not formed.
Nitrates.
Acid formed in dextrose.
White of egg is slowly peptonized.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

FAMILY V. BACILLACEAE FISCHER, 1895.

Rods producing endospores, usually Gram-positive. Flagella, when present, generally peritrichous. Often decompose protein media actively through the agency of enzymes.

Key to the genera of family Bacillaceae

A. Aerobic forms, mostly saprophytes.
Genus I. *Bacillus*, p. 414.
B. Anaerobic forms. Often parasitic.
Genus II. *Clostridium*, p. 467.

Genus I. Bacillus *Cohn, 1872.*

Aerobic forms. Mostly saprophytes. Generally liquefy gelatin. Often occur in long chains and form rhizoid colonies. Form of rod usually not greatly changed at sporulation. Young organisms are Gram-positive.

The type species is *Bacillus subtilis* (Ehrenberg) Cohn.

Key to the species of genus Bacillus

I. Aerobic, facultative. Mesophilic. Motile.
A. Spores central.
1. Rods swollen at sporulation.
a. Without pigment formation.
b. Do not form long chains.
c. Gelatin liquefied.
d. Nitrates reduced.
e. Litmus milk alkaline peptonized. A very common organism.
1. *Bacillus subtilis.*
ee. Litmus milk acid, coagulation and gas.
2. *Bacillus aerosporus.*
dd. Nitrates not reduced.
3. *Bacillus platychoma.*
cc. Gelatin not liquefied.
d. Milk not coagulated.
e. Nitrates reduced.
4. *Bacillus closteroides.*
ee. Nitrates not reduced.
5. *Bacillus fusus.*
6. *Bacillus cytaseus.*
bb. Form long chains.

c. Gelatin liquefied.
d. Liquefaction crateriform to saccate.
e. Milk not coagulated; peptonized.
f. Pellucid dots on surface of agar slant.
7. *Bacillus cereus.*
ff. No pellucid dots on agar culture.
8. *Bacillus mycoides.*
ee. Milk acid; not coagulated.
f. Acid and gas in carbohydrate media.
9. *Bacillus polymyxa.*
dd. Liquefaction infundibuliform.
e. Milk acid; coagulated; peptonized.
10. *Bacillus prausnitzii.*
ee. Milk coagulated; peptonized.
11. *Bacillus tumescens.*
ee. Milk not coagulated; peptonized.
12. *Bacillus graveolens.*
cc. Gelatin not liquefied.
d. Milk not coagulated.
13. *Bacillus amarus.*
dd. Milk acid; coagulated.
14. *Bacillus coagulans.*
aa. Yellow pigment formed.
b. Occur singly and in pairs.
c. Gelatin liquefied.
d. Liquefaction stratiform.
e. Milk not coagulated; peptonized.
15. *Bacillus simplex.*
dd. Liquefaction crateriform.
e. Milk not coagulated; peptonized.
f. Starch hydrolyzed.
16. *Bacillus petasites.*
ff. Starch not hydrolyzed.
17. *Bacillus cohaerens.*
ee. Milk unchanged.
f. Starch hydrolyzed.
g. Yellow growth on agar.
18. *Bacillus luteus.*
gg. White growth on agar.
19. *Bacillus amylolyticus.*
ddd. Liquefaction napiform.
e. Milk unchanged.
20. *Bacillus centrosporus.*
2. Rods not distinctly swollen at sporulation.
a. Without pigment.
b. Occur singly, in pairs or short chains

c. Gelatin liquefied.
d. Liquefaction saccate.
e. Milk not coagulated; peptonized.
f. Growth poor in sugar broths.
21. *Bacillus megatherium.*
dd. Liquefaction crateriform.
e. Milk acid; not coagulated.
22. *Bacillus lactis.*
23. *Bacillus albus.*
ee. Milk acid; coagulated; not slimy.
f. Starch is hydrolyzed.
24. *Bacillus albolactis.*
eee. Milk acid; coagulated; slimy.
f. Gas formed in lactose media.
25. *Bacillus hessii.*
eeee. Milk slightly acid; peptonized.
f. Acid in dextrose.
26. *Bacillus laterosporus.*
ff. Acid in dextrose, lactose and sucrose.
27. *Bacillus alvei.*
fff. Acid in mannitol, glycerol and salicin.
28. *Bacillus peptogenes.*
ddd. Liquefaction stratiform.
e. Milk unchanged.
29. *Bacillus robur.*
30. *Bacillus evanidus*
ee. Milk alkaline.
31. *Bacillus freudenreichii*
dddd. Liquefaction infundibuliform.
e. Milk coagulated; peptonized.
f. Starch hydrolyzed.
32. *Bacillus ruminatus.*
33. *Bacillus danicus.*
ddddd. Liquefaction saccate.
34. *Bacillus silvaticus.*
cc. Gelatin not liquefied.
d. Milk peptonized.
35. *Bacillus psychrocartericus.*
dd. Milk unchanged.
36. *Bacillus aminovorans.*
37. *Bacillus hesmogenes.*
aa. Pigment creamy-white to yellow.
b. Occur singly and in pairs.
c. Gelatin liquefied.
d. Liquefaction crateriform.
e. Milk soft coagulum; peptonized.

f. Blood serum liquefied.
g. Potato culture white to pink.
38. *Bacillus vulgatus.*
ee. No coagulation; peptonized.
f. Blood serum liquefied.
g. Potato culture gray to brownish.
39. *Bacillus mesentericus.*
ff. Blood serum not liquefied.
g. Starch hydrolyzed.
40. *Bacillus pumilus.*
41. *Bacillus brevis.*
gg. Starch hydrolyzed slightly.
42. *Bacillus lacticola.*
dd. Liquefaction stratiform.
e. Milk not coagulated; peptonized.
43. *Bacillus teres.*
ddd. Liquefaction infundibuliform.
44. *Bacillus agri.*
aaa. Pigment yellow to brownish.
b. Occur singly and in pairs.
c. Gelatin liquefied.
d. Liquefaction stratiform.
e. Milk not coagulated; peptonized.
f. Starch hydrolyzed.
45. *Bacillus parvus.*
46. *Bacillus globigii.*
dd. Liquefaction infundibuliform.
e. Milk not coagulated; peptonized.
47. *Bacillus fusiformis.*
cc. Gelatin not liquefied.
48. *Bacillus sphaericus.*
49. *Bacillus morulans.*
aaaa. Form black pigment.
b. Occur singly and in pairs.
c. Gelatin liquefied.
d. Liquefaction crateriform.
e. Milk not coagulated; peptonized.
f. Potato culture white to pink.
50. *Bacillus aterrimus.*
ff. Potato culture gray, becoming black.
51. *Bacillus niger.*

B. Spores terminal.
1. Rods swollen at sporulation.
a. Without pigment.
b. Occur singly and in pairs.
c. Gelatin liquefied.

d. Form of liquefaction not given.
52. *Bacillus pandora.*
dd. Liquefaction crateriform.
e. Milk not coagulated.
53. *Bacillus terminalis.*
54. *Bacillus serositidis.*
ddd. Liquefaction infundibuliform.
e. Milk acid; coagulated.
55. *Bacillus asterosporus.*
56. *Bacillus novus.*
cc. Gelatin not liquefied.
d. Milk acid; coagulated.
57. *Bacillus macerans.*
dd. Milk acid; not coagulated.
58. *Bacillus lautus.*
ddd. Milk unchanged.
59. *Bacillus tritus.*
aa. Pigment yellow.
b. Occur singly and in pairs.
c. Gelatin liquefied.
d. Milk alkaline; peptonized.
60. *Bacillus lactimorbus.*
cc. Gelatin slowly liquefied.
d. Milk unchanged.
61. *Bacillus imminutus.*
ccc. Gelatin not liquefied.
d. Milk not coagulated.
62. *Bacillus pseudotetanicus.*
dd. Milk slightly acid; coagulated.
e. Acid in dextrose, lactose and sucrose.
63. *Bacillus circulans.*
ee. Ferments arabinose, xylose and mannitol.
64. *Bacillus esterificans.*
2. Rods not swollen at sporulation.
a. Without pigment.
b. Occur singly, in pairs and in chains.
c. Gelatin liquefied.
d. Milk acid; coagulated.
65. *Bacillus flexus.*
dd. Milk unchanged.
66. *Bacillus pabuli.*
cc. Gelatin not liquefied.
d. Milk unchanged.
67. *Bacillus sublustris.*

II. Aerobic, facultative. Mesophilic. Non-motile.
- A. Spores central.
  - 1. Rods not swollen at sporulation.
    - a. Without pigment.
    - b. Form long chains.
    - c. Gelatin liquefied.
    - d. Liquefaction stratiform.
    - e. Milk acid; coagulated.
      - 68. *Bacillus anthracis.*
    - dd. Liquefaction infundibuliform.
    - e. Starch not hydrolyzed.
    - f. Blood serum liquefied.
      - 69. *Bacillus panis.*
    - ff. Blood serum not liquefied.
      - 70. *Bacillus adhaerens.*
      - 71. *Bacillus viridi-glaucescens.*
    - ddd. Liquefaction crateriform.
      - 72. *Bacillus fulminans.*
    - cc. Gelatin not liquefied.
    - e. Starch is hydrolyzed.
      - 73. *Bacillus aurantius.*

III. Aerobic, facultative. Thermophilic. Motile.
- A. No pigment formed.
  - 1. Spores central.
    - a. Rods not swollen at sporulation.
    - b. Milk acid; coagulated.
    - c. Starch hydrolyzed.
    - d. Gelatin liquefied.
      - 74. *Bacillus thermodiastaticus.*
    - aa. Rods swollen at sporulation.
    - b. Milk slightly acid, becoming alkaline.
    - c. Starch not hydrolyzed.
    - d. Gelatin not liquefied.
      - 75. *Bacillus nondiastaticus.*
    - cc. Starch hydrolyzed.
    - d. Gelatin may or may not be liquefied.
      - 76. *Bacillus lobatus.*
    - dd. Gelatin not liquefied.
      - 77. *Bacillus thermoamylolyticus.*
  - 2. Spores terminal.
    - a. Rods swollen at sporulation.
    - b. Milk unchanged.
    - c. Starch not hydrolyzed.
    - d. Gelatin not liquefied.
      - 78. *Bacillus thermoalimentophilus.*

cc. Starch hydrolyzed.
d. Gelatin not liquefied.
79. *Bacillus thermocellulolyticus.*
80. *Bacillus cylindricus.*
81. *Bacillus stearothermophilus.*
bb. Milk acid; no coagulation.
c. Starch not hydrolyzed.
d. Gelatin not liquefied.
82. *Bacillus thermotranslucens.*
cc. Starch slightly hydrolyzed.
d. Gelatin not liquefied.
83. *Bacillus thermononliquefaciens.*
bbb. Milk acid; coagulated.
c. Starch not hydrolyzed.
d. Gelatin liquefied.
84. *Bacillus thermoliquefaciens.*
cc. Starch hydrolyzed.
d. Gelatin liquefied.
85. *Bacillus kaustophilus.*
bbbb. Milk becoming alkaline.
c. Starch hydrolyzed.
d. Gelatin liquefied.
e. Growth at 20°C.
86. *Bacillus thermoindifferens.*
ee. No growth at 20°C.
87. *Bacillus aerothermophilus.*
88. *Bacillus michaelisii.*

B. Form yellow pigment.
1. Spores central.
a. Rods not swollen at sporulation.
b. Occur singly and in pairs.
c. Starch not hydrolyzed.
89. *Bacillus robustus.*
90. *Bacillus losanitchi.*
bb. Occur singly, in pairs and short chains.
c. Starch hydrolyzed.
91. *Bacillus viridulum.*
2. Spores terminal.
a. Rods not swollen at sporulation.
b. Occur singly, in pairs and short chains.
c. Starch not hydrolyzed.
92. *Bacillus calidus.*
cc. Starch hydrolyzed.
93. *Bacillus tostus.*

IV. Aerobic, facultative. Thermophilic. Non-motile.
A. No pigment formed.
1. Spores terminal.
a. Milk acid; coagulated.
94. *Bacillus calidolactis.*
aa. Milk slimy, not coagulated.
95. *Bacillus pepo.*

1. **Bacillus subtilis** Cohn *emend.* Prazmowski. (Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft 2, 1872, 175; *ibid.*, *1*, Heft 3, 1875, 188; *ibid.*, *2*, Heft 2, 1876, 249; Prazmowski, Untersuchungen über die Entwicklungsgeschichte und Fermentwirkung einiger Bacterien-Arten. Inaug. Diss., Leipzig, 1880.)

(Prototype: *Vibrio subtilis* Ehrenberg, Infusionsthierchen als vollkommene Organismen, Leipsig, 1838.)

Rods: 0.8 by 1.5 to 2.0 microns, occurring singly or sometimes in short chains. Motile, with peritrichous flagella. Spores central, 0.6 to 0.8 micron in size. Remains of sporangium disappear rapidly. Germination equatorial. Cells store glycogen as reserve material. Gram-positive.

Gelatin colonies: Circular, whitish, entire, becoming creamy-white, liquefying.

Gelatin stab: Whitish surface growth. Liquefaction stratiform to saccate or crateriform.

Agar colonies: Small, grayish, amoeboid with crenate margin.

Agar slant: Thin, grayish-white, butyrous, glistening, spreading, adherent.

Broth: Turbid, with fragile pellicle and grayish sediment.

Litmus milk: Alkaline; peptonized.

Potato: Luxuriant, warty, gray, becoming pink with vesicles over surface.

Indol not formed.

Nitrates are reduced.

Acid in dextrose and sucrose.

Starch is hydrolyzed.

Blood serum slowly liquefied.

Slight H_2S production.

Aerobic, facultative.

Optimum temperature 30° to 37°C. Will grow between 10° and 56°C.

Habitat: Soil.

Note: This description of *Bacillus subtilis* has been revised by H. J. Conn to correspond in all details with the characters of the so-called Marburg strain of *Bacillus subtilis* (Jour. Inf. Dis., *46*, 1930, 341). He has also revised the descriptions of *Bacillus cereus*, *B. mycoides*, *B. megatherium* (N. Y. Agr. Exp. Sta., Tech. Bull. 58, 1917).

2. **Bacillus aerosporus** Greer. (Lactose fermenting spore former, Norton and Weight, Am. Jour. Pub. Health, 14, 1924, 1019; Greer, Jour. Infect. Dis., *42*, 1928, 508.)

Rods: 0.6 by 3.0 microns, occurring singly and in pairs. Spores oval, central, of larger diameter than the rods. Motile. Gram-positive.

Gelatin stab: Liquefied.

Agar colonies: Small, circular, gray.

Agar slant: Thin, delicate, transparent growth.

Broth: Turbid.

Litmus milk: Acid, coagulation and gas formation.

Potato: Gray, slimy, with gas formation.

Indol is not formed.

Nitrates are reduced.

Methyl red negative.

Voges-Proskauer positive.

Acid and gas in dextrose, levulose, galactose, xylose, maltose, lactose, sucrose, raffinose, dextrin, salicin, inulin and rhamnose. No action on dulcitol or adonitol.

H_2S is formed.

Aerobic, faculative.

Optimum temperature 37°C.

Habitat: Soil and water.

3. **Bacillus platychoma** Gray and Thornton. (Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 93.)

Rods: 1.0 to 1.5 by 3.0 to 7.0 microns. Motile with peritrichous flagella. Spores central and of greater diameter than the vegetative rods. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: Saccate to crateriform liquefaction.

Agar colonies: Circular, whitish, convex, granular.

Agar slant: Filiform, whitish, flat, smooth, glistening.

Broth: Turbid.

Litmus milk.

Potato.

Indol.

Nitrates not reduced.

Starch hydrolyzed.

Acid from dextrose.

Attack phenol.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Soil.

4. **Bacillus closteroides** Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 93.)

Rods: 1.0 by 2.0 to 5.0 microns. Motile, with peritrichous flagella. Spores central, with marked swelling of the cell. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: No growth or slight development.

Agar colonies: Amoeboid to dendroid, whitish, smooth, granular, entire.
Agar slant: Filiform, whitish, flat, smooth, spreading.
Broth: Turbid.
Litmus milk.
Potato.
Indol.
Nitrates reduced to nitrites.
Starch hydrolyzed.
Acid from dextrose, occasionally also from lactose, maltose and sucrose.
Attack phenol.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Manure and soil.

5. **Bacillus fusus** Batchelor. (Jour. of Bact., *4*, 1919, 27.)

Rods: Thin, delicate, 0.75 by 2.25 to 4.5 microns, occurring singly and in pairs. Motile. Spores central, 1.125 by 2.25 microns. Gram-positive.
Gelatin colonies: Small, circular, smooth.
Gelatin stab: No liquefaction.
Agar colonies: Small, circular, smooth.
Agar slant: White, beaded, becoming abundant, adherent.
Broth: Turbid, with gray, granular sediment.
Litmus milk: Gradual reduction of litmus.
Potato: Moist, creamy, abundant, at times pale brown in color.
Indol not formed.
Nitrates not reduced.
Blood serum shows faint, dry growth.
Acid formed in dextrose, lactose and sucrose.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal of infants.

6. **Bacillus cytaseus** McBeth and Scales. (Bull. 266, U. S. Dept. of Agr., Bur. of Plant Industry, 1913, 39.)

Rods: 0.2 to 0.5 by 3.0 to 5.0 microns, occurring singly, in pairs and short chains. Motile. Spores oval, 0.7 to 1.0 by 1.4 to 2.6 microns, central. Gram-positive.
Gelatin stab: Short beaded growth in stab. No liquefaction.
Cellulose agar colonies: Light gray, homogeneous to granular, with raised center, lobate margin.
Agar slant: Flat, vitreous to faint gray, abundant growth on potato agar and cellulose agar.
Broth: No growth.
Litmus milk: No growth.
Potato: No growth.
Indol not formed.
Nitrates not reduced.

No acid or gas in sugar media.
Starch is hydrolyzed.
Aerobic, facultative.
Optimum temperature 20–25°C.
Habitat: Soil.

7. **Bacillus cereus** Frankland and Frankland. (Philosoph. Transact. of the Royal Soc. of London, *178*, B. 1887, 279; *Bacillus ellenbachensis alpha* Stutzer, Cent. f. Bakt., II Abt., *4*, 1898, 31; *Bacillus ellenbachensis* Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 540; *Bacterium petroselini* Buchard, Arbeiten bakt. Inst. der techn. Hochschule zu Karlsruhe, *2*, 1902, 39.

The following are given as possible synonyms by Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 540; *Bacillus ramosus liquefaciens* Flügge, Die Mikroorganismen, 1886, 342; *Bacillus stoloniferus* Phol, Cent. f. Bakt., *11*, 1892, 142; *Bacillus limosus* Russell, Zeitschr. f. Hyg., *11*, 1892, 196; *Bacillus brevis o* Flügge, Zeitschr. f. Hyg., *17*, 1894, 294; *Bacillus lutulentus* Kern, Arbeiten a. d. bakt. Inst. d. techn. Hochschule zu Karlsruhe, *1*, 1901, 402; *Bacillus cursor* Burchard, Arbeiten bakt. Inst. der techn. Hochschule zu Karlsruhe, *2*, 1902, 25; *Bacillus luxosus* Burchard, ibid., 37; *Bacillus goniosporus* Burchard, ibid., 14; *Bacterium tergescens* Burchard, *ibid.*, 18.)

Rods: 0.8 to 1.0 by 2.25 to 4.0 microns, occurring singly and in long chains; on glucose broth often much longer. Motile with peritrichous flagella. Spores central, 0.8 to 1.0 by 1.1 to 1.5 microns. Often occurring in chains with remains of sporangium persistant. Germination polar. Cells store glycogen as reserve material. Gram-positive.

Gelatin colonies: Filamentous, grayish, irregular margin.

Gelatin stab: Liquefaction crateriform to saccate, becoming stratiform.

Agar colonies: Circular, raised, dense, refractive, entire.

Agar slant: Abundant, thick, white, membraneous or mealy, becoming yellowish-white.

Broth: Turbid, with ring formation and fragile pellicle. Flocculent sediment.

Litmus milk: No coagulation. Rapid peptonization.

Potato: Thick, white, moist, becoming yellow to brown.

Indol not formed.

Nitrates reduced. (Some strains do not reduce.)

Acid in dextrose and sucrose.

Blood serum liquefied in 10 days.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

7A. **Bacillus cereus** var. **fluorescens** Laubach. (Jour. Bact., *1*, 1916, 508: *Bacillus fluorescens* Bergey et al., Manual, 1st ed., 1923, 287.)

This organism varies from *Bacillus cereus* in the production of a yellowish green fluorescence, in agar, gelatin, potato, milk, and broth media.

8. **Bacillus mycoides** Flügge. (Die Mikroorganismen, 1886, 324.)

Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 589, gives the following as probable synonyms:

Wurzelbacillus, Eisenberg, Bakt. Diag., 1886; *Bacillus figurans* Crookshank, Manual, 1886; *Bacillus ramosus* Eisenberg, Bakteriologische Diagnostik, *3*, 1891, 126; *Bacillus ramosus* Frankland, Ueber einige typische Mikroorg. in Wasser und in Boden, Zeitschr. f. Hyg., *2*, 1889, 388; Wurzelbacillus, Fränkel, Bakterienkunde, 1890, 241; *Bacillus radicosus* Zimmermann, Die Bakterien unserer Trink. u. Nutzwässer, inbesondere das Wasser der Chemnitzer Wasserleitung, I Reihe, 30; *Bacillus implexus* Zimmermann, ibid.; *Bacterium casei* Adametz, Bakt. Untersuchung über den Reifeprozess der Kase, Landw. Jahrb., *18*, 1889, 248; *Bacillus intricatus* Russell (Cladothrix), Zeitschr. f. Hyg., *11*, 1892, 191; *Bacillus brassicac* Pommer, Beitrag zur kenntnis der fadenbildenden Bakterien, Mitt. aus dem botan. Institute zu Graz, 1886; Koch, Botan. Zeitung, 1888.

Rods: 0.8 to 1.0 by 2.0 to 4.0 microns, occurring in long chains; in glucose broth often much longer. Sluggishly motile. Motile with peritrichous flagella. Spores central, 0.8 to 1.0 by 1.4 to 2.2 microns. Often occurring in chains with remains of sporangium persistant. Germination polar. Gram-positive. Cells store fat as reserve material. Morphologically practically identical with *Bacillus cereus*.

Gelatin colonies: Whitish, filamentous, fimbriate.

Gelatin stab: Arborescent growth in stab. Crateriform to saccate liquefaction.

Agar colonies: Grayish, spreading, rhizoid.

Agar slant: Whitish, soft, glistening, rhizoid, becoming dull.

Broth: Slightly turbid, sometimes with wrinkled fragil pellicle.

Litmus milk: No coagulation; slow peptonization.

Potato: Whitish, homogeneous to granular, becoming brownish.

Indol not formed.

Nitrates are reduced.

Acid in dextrose and sucrose.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

9. **Bacillus polymyxa** (Prazmowski) Migula. (*Clostridium polymyxa* Prazmowski, Inaug. Diss., Leipzig, 1880, 23; Migula, System der Bakterien, 1900, 638; Further description by Gruber, Cent. f. Bakt., II Abt., *14*, 1905, 353.)

Rods: 0.45 by 1.75 to 7.0 microns, occurring singly and in chains. Motile with peritrichous flagella. Spores central, 1.75 by 2.6 microns. Gram-positive.

Gelatin colonies: Grayish-white, flat, spreading, translucent, glistening.

Gelatin stab: Slight, white, dull surface growth. Liquefaction saccate.

Agar colonies: Circular, grayish-white, finely granular, glistening, lobulated.

Agar slant: Abundant, grayish-white growth.

Broth: Turbid, with grayish pellicle and flocculent sediment.

Litmus milk: Acid, with gas formation. Not coagulated.

Potato: Thin, grayish-white layer.

Indol not formed.

Nitrates not reduced.

Acid and gas in dextrose, lactose, galactose, arabinose, xylose, maltose, sucrose, raffinose, dextrin, starch and mannitol. CO_2 is formed but not H_2.

Starch is hydrolyzed. When grown on starch media the cells store granulose as shown by blue color when tested with iodin solution.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from pasteurized milk.

10. **Bacillus prausnitzii** Trevisan. (*Bacillus ramosus liquefaciens* Flügge, Die Mikroorganismen, 1886, 324; Trevisan, I Generi e Spec. d. Batteriacee, 1889, 2.)

Rods: 0.6 to 0.75 by 3.0 to 5.0 microns, occurring singly, in pairs and short chains. Motile with peritrichous flagella. Spores central, 0.75 to 1.0 by 1.5 to 2.0 microns. Gram-positive.

Gelatin colonies: Interlacing filaments, spreading.

Gelatin stab: Arborescent growth in stab. Liquefaction infundibuliform.

Agar colonies: Spreading, filamentous, gray.

Agar slant: Abundant, gray, dull, spreading, filamentous.

Broth: Turbid, with granular pellicle and flocculent sediment.

Litmus milk: Acid. Coagulation. Peptonization.

Potato: Yellowish-gray, viscid, spreading.

Indol not formed.

Nitrates are reduced.

Acid in dextrose, lactose and sucrose.

Starch not hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

11. **Bacillus tumescens** Zopf. (Die Spaltpilze, 1885, 82.)

Gottheil, Cent. f. Bakt., II Abt., 7, 1901, 492, gives the following as possible synonym:

Bacillus granulosus Russell, Zeitschr. f. Hyg., *11*, 1892, 99.

Rods: 1.4 to 1.5 by 3.0 to 3.5 microns, occurring singly and in short chains. Spores central, 0.8 to 1.0 by 1.5 to 2.0 microns. Motile with peritrichous flagella. Gram-positive. Cells store fat as reserve material.

Gelatin colonies: Irregularly circular, whitish, homogeneous, undulate.
Gelatin stab: Slow, infundibuliform liquefaction.
Agar colonies: Circular, entire, convex, compact, gray.
Agar slant: Thin, whitish, homogeneous, slimy, becoming yellowish, opaque.
Broth: Turbid, with grayish sediment.
Litmus milk: Slowly coagulated; peptonized.
Potato: Whitish, moist, raised, glistening, vermiform, contoured.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, lactose and sucrose.
Starch is hydrolyzed.
Blood serum is liquefied.
Aerobic, facultative.
Optimum temperature 30°C. Will grow at 45° to 50°C.
Habitat: Soil and sea water.

12. **Bacillus graveolens** Gottheil. (Cent. f. Bakt., II Abt., 7, 1901, 496.)
Gottheil (*loc. cit.*) gives the following as a possible synonym: *Bacillus mesentericus vulgatus* Flügge, Die Mikroorganismen, 1886, 322.
Rods: 0.4 to 0.7 by 1.4 to 1.5 by 2.5 to 3.0 microns, occurring singly, in pairs and in chains. Motile. Spores central, 1.0 to 1.7 by 1.9 to 2.5 microns. Gram-positive. Cells store fat as reserve material.
Gelatin colonies: White, circular, homogeneous, entire.
Gelatin stab: Slow, infundibuliform liquefaction.
Agar slant: Thin, membranous, finely wrinkled, whitish, dull.
Broth: Turbid, with scant sediment.
Litmus milk: Not coagulated; peptonized.
Potato: Gray, slimy, wrinkled. Medium is darkened.
Indol not formed.
Nitrates not reduced.
Acid in dextrose and sucrose.
Starch is hydrolyzed.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 37°C. Will grow at 45° to 50°C.
Habitat: Soil.

13. **Bacillus amarus** Hammer. (Research Bul. No. 52, Iowa Agr. Exp. Sta., 1919, 198.)
Rods: 0.5 to 0.7 by 2.1 to 4.7 microns occurring singly, occasionally in pairs and short chains. Motile, possessing peritrichous flagella. Spores central, 0.8 by 1.5 microns, rods swollen at sporulation. Gram-positive.
Gelatin stab: No liquefaction.
Agar colonies: Small, white, entire.
Agar slant: White, echinulate.
Broth: Turbid, with gray sediment.

Litmus milk: Litmus partly reduced. No coagulation.
Potato: Limited, white.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, fructose, galactose and maltose.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from evaporated milk.

14. **Bacillus coagulans** Hammer. (Research Bul. No. 19, Iowa Agr. Exp. Sta., 1915, 129.)

Rods: 0.5 to 0.7 by 1.6 to 7.0 microns, occurring singly and in short chains. Spores, small, central. Motile, possessing peritrichous flagella. Gram-positive.

Gelatin stab: No liquefaction.
Agar colonies: White, glistening.
Agar slant: White, glistening, echinulate, becoming yellowish-gray.
Broth: Turbid, with gray pellicle and sediment.
Litmus milk: Acid; coagulated.
Potato: Dirty-white, glistening, spreading.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, levulose, galactose, maltose, lactose and raffinose.
Aerobic, facultative.
Optimum temperature 55°C.
Habitat: Isolated from evaporated milk.

15. **Bacillus simplex** Gottheil. (Cent. f. Bakt., II Abt., 7, 1901, 685.)

Gottheil (*loc. cit.*) gives the following as possible synonyms: *Bacillus loxosporus* Burchard, Arb. a. d. bakt. Inst. d. Techn. Hochschule zu Karlruhe, *2*, 1902, 49; *Bacillus natans* Kern, Arb. a. d. bakt. Inst. der techn. Hochschule zu Karlsruhe, *1*, 1901, 413; *Bacillus vacuolosus* Sternberg, Manual Bacteriology, 1893, 717.

Rods: 0.9 by 3.0 to 5.0 microns, occurring singly, in pairs, and in chains. Motile with peritrichous flagella. Spores central, 0.8 by 1.4 to 1.7 microns. Cells store glycogen as reserve material. Gram-positive.

Gelatin colonies: Circular, whitish, entire.
Gelatin stab: Whitish surface growth. Liquefaction stratiform.
Agar colonies: Thin, translucent, ameboid.
Agar slant: Thin, spreading, translucent, wrinkled, adherent, becoming yellowish.
Broth: Slightly turbid.
Litmus milk: No coagulation. Peptonization.
Potato: Thick, moist, slimy, yellowish-brown.
Indol not formed.
Nitrates are reduced.
Acid in dextrose.

Starch not hydrolyzed.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 30°C. Will grow at 35° to 40°C.
Habitat: Soil.

16. **Bacillus petasites** Gottheil. (Cent. f. Bakt., II Abt., 7, 1901, 535.)

Gottheil (*loc. cit.*) gives the following as a possible synonym: *Bacillus lacteus* Lembke, Arch. f. Hyg., *29*, 1897, 323. Chester (Delaware Coll. Agr. Exp. Sta., 15th. Ann. Rept., 1904, 70) considers *Bacillus petasites* a synonym of *Bacillus megatherium*. See Conn., H. J., N. Y. Agr. Exp. Sta., Tech. Bull. 58, 1917, 9 for a further discussion of the probable identity of this organism with *Bacillus megatherium.*

Rods: 0.4 to 1.5 by 2.0 to 3.0 microns, occurring singly and occasionally in pairs and in short chains. Motile with peritrichous flagella. Spores central, 0.8 to 1.1 by 1.7 to 2.2 microns. Gram-positive. The cells store fat as reserve material.

Gelatin colonies: Irregular, white, homogeneous, entire.

Gelatin stab: Yellowish surface growth. Slow crateriform liquefaction.

Agar colonies: Circular, thick, white to cream color, becoming yellowish-brown.

Agar slant: Smooth, whitish, glistening, homogeneous. In eight days the upper portion becomes reddish and the lower portion intense yellow.

Broth: Turbid.
Litmus milk: No coagulation. Peptonization.
Potato: Yellow, homogeneous, glistening.
Indol not formed.
Nitrates not reduced.
Acid in dextrose and sucrose.
Starch is hydrolyzed.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 35°C. Will grow at 45° to 50°C.
Habitat: Soil.

17. **Bacillus cohaerens** Gottheil. (Cent. f. Bakt., II Abt., 7, 1901, 458; Not *Bacillus cohaerens* Wright, Memoirs Nat. Acad. Sci., 7, 1895, 464.)

Gottheil (*loc. cit.*) gives the following as possible synonyms: *Bacillus bipolaris* Burchard, Arb. a. d. bakt. Inst. d. techn. Hochschule zu Karlsruhe *2*, 1902, 34; *Bacillus cylindrosporus* Burchard, ibid., 31; *Bacillus filiformis* Tils, Zeitschr. f. Hyg., 1890, 17; *Bacillus vermicularis* Frankland, Zeitsch. f. Hyg., *6*, 1886, 384; *Bacillus virgatus* Kern, Arb. a. d. bakt. Inst. d. techn. Hochschule zu Karlsruhe, *1*, 1901, 416; *Bacillus lactis albus* Eisenberg, Bakteriologische Diagnostik, *3*, 1891, 110.

Rods: 0.35 to 0.55 by 0.75 to 2.25 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.8 to 1.0 by 1.7 to 2.2 microns. Cells store glycogen as reserve material. Gram-positive.

Gelatin colonies: White, irregular, lobed.

Gelatin stab: Irregular, whitish surface growth. Slow crateriform liquefaction.

Agar colonies: Circular, yellowish-white, folded.

Agar slant: Thin, smooth, glistening, homogeneous, slimy, becoming yellow.

Broth: Turbid with dense, flocculent pellicle.

Litmus milk: Litmus reduced. Peptonization.

Potato: Thin, moist, yellow, spreading.

Indol not formed.

Nitrates not reduced.

Acid in dextrose and sucrose.

Starch not hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C. Will grow at 35° to 40°C.

Habitat: Soil.

18. **Bacillus luteus** Garbowski. (*Bacillus luteus sporogenes* Smith and Baker, Cent. f. Bakt., II Abt., *4*, 1898, 788; Garbowski, Cent. f. Bakt., II Abt., *19*, 1907, 641.)

Rods: 1.4 to 1.6 by 6.0 to 8.0 microns, occurring singly and in chains. Spores central, 0.8 to 1.4 by 1.0 to 2.6 microns. Motile with two to four peritrichous flagella. Gram-positive.

Gelatin colonies: Circular, yellow, with three concentric zones, the central one showing most pigment.

Gelatin stab: Slow, crateriform liquefaction.

Agar colonies: Circular, yellow, homogeneous, entire.

Agar slant: Spreading, bright yellow, becoming brownish-red, glistening.

Broth: Turbid.

Litmus milk: Unchanged.

Potato: Deep yellow, moist growth.

Indol not formed.

Nitrates not reduced.

Acid in.

Starch is hydrolyzed.

Blood serum.

Aerobic, facultative.

Optimum temperature 35°C.

Habitat: Isolated from beet sugar.

19. **Bacillus amylolyticus** Kellerman and McBeth. (Cent. f. Bakt., II Abt., *34*, 1912, 490.)

Rods: 2.8 to 4.5 by 0.5 to 0.8 microns, do not form long chains. Spores central, swelling rod to twice natural size, 1.5 to 2.0 by 0.8 to 1.0 microns in size. Gram negative.

Gelatin stab: Liquefaction crateriform in young cultures, stratiform in old.

Agar slant: White, viscid, beaded.
Agar colonies: Circular, flat, smooth, viscid, gray white.
Broth: Clouded.
Litmus milk: Reddened slowly.
Potato: No growth.
Indol not formed.
Acid but no gas from dextrose, sucrose, lactose, maltose, glycerol, mannitol, and starch.
Starch hydrolyzed. Causes destruction of cellulose.
Aerobic, facultative.
Optimum temperature:
Habitat: Isolated from manure.

20. **Bacillus centrosporus** Ford. (Jour. of Bact., *1*, 1916, 524.)
Rods: 0.375 to 0.5 by 3.0 to 4.5 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.625 by 1.125 to 1.5 microns. Gram-positive.
Gelatin colonies: Small, slowly developing, yellowish, surrounded by a hazy zone.
Gelatin stab: Liquefaction napiform.
Agar colonies: Circular, translucent, entire.
Agar slant: Dark, gray, moist, non-adherent.
Broth: Turbid, with fragile pellicle.
Litmus milk: Unchanged, except partial reduction.
Potato: Moist, yellow, becoming brown or reddish-brown.
Indol not formed.
Nitrates not reduced.
Acid in none of the carbohydrate media.
Starch not hydrolyzed.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Isolated from intestinal contents of child.

21. **Bacillus megatherium** De Bary. (Vergleichende Morph. u. Biol. d. Pilze, 1884, 499.)
Neide, Cent. f. Bakt., II Abt., *12*, 1904, 11, gives the following as possible synonyms:
Bacterium hirtum Henrici, Arbeiten aus dem bakteriol. Inst. der techn. Hochschule zu Karlsruhe, 1898, 44; *Bacterium sessile* Klein, Cent. f. Bakt., *6*, 1889, 10; *Bacterium brassicae* Migula, Mitt. d. botan. Inst. Graz., 1886, *1*, 95; *Bacterium anthracoides* Kruse, Flügge, Mikoorganismen, *2*, 1896, 232); *Bacterium pseudoanthracis* Wahrlich, Bakteriol. Studien, Petersburg, 1890, 91, 26; *Bacterium flexile* Burchard, Arbeiten aus d. bakt. Inst. d. techen. Hochsch. Karlsruhe, *2*, 1901, 16.
Rods: 1.0 to 2.0 by 3.5 to 4.0 microns, occurring singly, in pairs and short chains. Old rods irregular in shape and often as large as 2.5 to 3.0 microns

in diameter. Motile with four to ten peritrichous flagella. Spores central, 0.8 to 1.25 by 1.5 to 2.0 microns. Germination polar. Gram-positive. The cells store fat as reserve material.

Gelatin colonies: Grayish-white, raised, glistening, entire.

Gelatin stab: Grayish-white surface growth. Small, white colonies in stab. Liquefaction crateriform to saccate.

Agar colonies: Circular, thick, white to cream color, entire.

Agar slant: Dirty white, smooth, glistening, slimy, the medium becoming brownish. Old cultures become yellowish-red with pellucid spots over the surface.

Broth: Poor growth, as in all liquid media.

Litmus milk: No coagulation. Peptonization.

Potato: Thick, white, mealy, becoming pale yellow.

Indol not formed.

Nitrates: No growth in nitrate broth.

Poor growth in sugar broths.

Starch is hydrolyzed.

Blood serum is liquefied in 5 days at 22°C.

Aerobic, facultative.

Optimum temperature 35°C. Will grow at 45° to 50°C.

Habitat: Soil, water, and putrefying materials.

22. **Bacillus lactis** Flügge. (Zeitschr. f. Hyg., *17*, 1894, 294.)

Neide, Cent f. Bakt., II Abt., *12*, 1904, 337, gives the following as possible synonyms:

Bacillus lactis I Flügge, Zeitschr. f. Hyg., *17*, 1894, 294; *Bacillus cylindrosporus* Burchard, Arb. aus d. Bakt. Inst. d. techn. Hochsch., Karlsruhe, *2*, 1902, 31; *Bacillus amarificans* Migula, System der Bakterien, 1900, 584; *Bacillus agglomeratus*, synonymous with Bacillus No. 5 Pansini, Virchow's Archiv., *122*, 1890, 441; *Bacillus lutulentus* Kern, Arb. aus. d. bakt. Inst. d. techn. Hochsch. Karlsruhe, *1*, 1901, 402.

Rods: 0.2 to 1.4 by 3.5 to 4.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.9 to 1.0 by 2.0 microns. Gram-positive. Cells store fat and volutin as reserve materials.

Gelatin colonies: Small, whitish, entire to undulate.

Gelatin stab: Glistening, white surface growth. Liquefaction crateriform to stratiform.

Agar colonies: Grayish-white, thin, homogeneous.

Agar slant: Grayish-white, medium becoming brownish.

Broth: Turbid.

Litmus milk: Acid. Not coagulated.

Potato: Thin, membranous, grayish, spreading.

Indol not formed.

Nitrates not reduced.

Starch not hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 39°C. Will grow at 40° to 45°C.

Habitat: Isolated from milk.

23. **Bacillus albus** (Sack) Bergey et al. (*Cellulomonas albus* Sack, Cent. f. Bakt., II Abt., *62*, 1924, 79; Bergey et al., Manual, 3rd ed., 1930, 398; Not *Bacillus albus* Copeland, Report of Filtration Commission, Pittsburgh, 1899, 344.)

Rods: 0.5 by 1.0 micron. Spores are formed. Motile. Gram-negative.

Gelatin colonies: Circular, white, entire.

Gelatin stab: Very slow liquefaction.

Agar colonies: Circular, white, soft, entire.

Agar slant: White, moist, layer.

Broth: Slight turbidity with thin pellicle and gray sediment.

Litmus milk: Acid. Litmus reduced.

Potato: Thick, soft, light brown layer.

Indol not formed.

Nitrates reduced to nitrites and ammonia.

H_2S formed.

Cellulose hydrolyzed.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

24. **Bacillus albolactis** Migula. (*Bacillus lactis albus* Löffler, Berlin. Klin. Wochenschr., 1887, 630; Migula, System der Bakterien, 1900, 577.)

Rods: 0.75 by 2.5 to 4.0 microns, occurring singly and in chains. Motile with peritrichous flagella. Spores central, 0.5 to 0.75 by 1.2 to 1.5 microns. Gram-positive.

Gelatin colonies: Circular, concentric, grayish, filamentous.

Gelatin stab: Liquefaction crateriform.

Agar colonies: Circular to bizarre, white, raised, curled.

Agar slant: Thick, white, smooth, glistening, spreading, slightly wrinkled.

Broth: Turbid, with gray pellicle and thick sediment.

Litmus milk: Acid; coagulation. Peptonization.

Potato: Thick, white, moist, becoming yellowish-brown. Medium darkened.

Indol not formed.

Nitrates reduced to nitrites.

Acid in dextrose, lactose and sucrose.

Starch is hydrolyzed.

Blood serum liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil. First isolated from boiled milk.

25. **Bacillus hessii** (Guillebeau) Kruse. (*Bacterium hessii* Guillebeau, Landwirtschaftl. Jahrb. d. Schweitz, *5*, 1891, 135; Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 210.)

Rods: 1.2 by 3.0 to 5.0 microns. Actively motile. Spores central; not swollen at sporulation. Gram-positive.

Gelatin colonies: Gray, rhizoid.

Gelatin stab: Villous growth in stab. Liquefaction.

Agar slant: Gray, filamentous.

Broth: Turbid, with slimy sediment.

Litmus milk: Acid; coagulated; slimy.

Potato: Thick, dirty-white layer.

Indol not formed.

Nitrates not reduced.

Gas in lactose media.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Slimy milk.

26. **Bacillus laterosporus** Laubach. (Jour. of Bact., *1*, 1916, 511.)

Rods: 0.375 to 0.5 by 1.125 to 4.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central and to one side, 0.75 to 0.875 by 1.5 microns. Gram-positive.

Gelatin colonies: Circular, gray, moist, entire.

Gelatin stab: Slow crateriform liquefaction.

Agar colonies: Irregular, flat, moist, transparent, with metallic luster.

Agar slant: Profuse, spreading, smooth, moist, with silvery metallic luster.

Broth: Slightly turbid, with flocculent pellicle.

Litmus milk: Soft coagulum; peptonization. Litmus reduced.

Potato: Dull, gray, granular, finely wrinkled.

Indol not formed.

Nitrates not reduced.

Acid in dextrose.

Starch not hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil and water.

27. **Bacillus alvei** Chesshire and Cheyne. (Jour. Royal Microscopical Soc., Ser. II, *5*, 592.)

Rods: 0.6 to 0.75 by 3.5 to 4.25 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.8 to 1.0 by 1.6 to 1.7 microns. Gram-positive. Cells store volutin as reserve material.

Gelatin colonies: Circular, gray, granular.

Gelatin stab: Slow surface growth. Slow, crateriform liquefaction.

Agar colonies: Barely visible, fimbriate.

Agar slant: Very slight development, thin translucent.
Broth: Turbid, with grayish pellicle.
Litmus milk: Acid; coagulated; peptonized.
Potato: Slowly developing grayish-white layer.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, lactose and sucrose.
Starch not hydrolyzed.
Blood serum not liquefied.
Aerobic to microaerophilic.
Optimum temperature 37°C. Will grow at 40° to 45°C.
Habitat: A secondary invader in European "foulbrood" of bees.

28. **Bacillus peptogenes** (Buchanan and Hammer) Bergey et al. (*Bacterium peptogenes* Buchanan and Hammer, Res. Bul., 22, Iowa Agr. Ex. Sta., 1915, 273; Bergey et al., Manual, 1st ed., 1923, 293.)

Rods: 0.5 to 0.7 by 1.3 to 5.1 microns, occurring singly and in chains. Non-motile. Gram-positive. Spores central; rods not swollen at sporulation.

Gelatin stab: Heavy, gray, surface growth. Crateriform to stratiform liquefaction.

Agar colonies: White, regular, almost black by reflected light.
Agar streak: Heavy, white, raised echinulate.
Broth: Turbid, with slimy sediment.
Litmus milk: Slightly acid, slimy, peptonized. Litmus reduced.
Potato: White, viscous.
Indol not formed.
Nitrates not reduced.

Acid formed in dextrose, levulose, maltose, lactose, raffinose, mannitol, inulin, salicin, starch and glycerol.

Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Isolated from contaminated milk.

29. **Bacillus robur** Neide. (Cent. f. Bakt., II Abt., *12*, 1904, 18.)

Neide (*loc. cit.*) gives the following as possible synonyms:

Bacillus cursor Burchard, Arbeit aus d. bakt. Inst. d. techn. Hochsch., Karlsruhe, *2*, 1902, 25; *Bacillus cereus* Frankland (Grace and Percy Frankland), Philosoph. Transact. of the Royal Society of London, *178*, 1887, B. 279. Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 540 gives *Bac. robur* and *Bac. cursor* as possible synonyms of *Bac. ellenbachiensis*.

Rods: 1.5 to 1.8 by 4.5 microns, occurring singly and in chains. Motile with peritrichous flagella. Spores central, 1.1 by 1.8 microns. Gram-positive. Cells store fat, glycogen and volutin as reserve materials.

Gelatin stab: Arborescent growth in stab. Liquefaction stratiform.
Agar colonies.

Agar slant: Small, isolated colonies, grayish-white, glistening, granular, fimbriate margin.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Thin, whitish layer.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Blood serum not digested.
Aerobic, facultative.
Optimum temperature 28°C. Will grow at 30° to 35°C.
Habitat: Soil.

30. **Bacillus evanidus** Grohmann. (Cent. f. Bakt., II Abt., *61*, 1924, 267.)
Rods: 1.0 by 1.0 to 4.0 microns. Spores are formed. Motile. Gram negative.
Gelatin colonies.
Gelatin stab: Liquefied.
Agar colonies: Circular, white.
Agar slant: Dirty-gray, filiform streak.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: Black layer.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

31. **Bacillus freudenreichii** (Miquel) Migula. (*Urobacillus freudenreichii* sive *Bacillus ureae* γ Miquel, Ann. de Micrographie, 1, 1889–1890, 367; Migula, System der Bakterien, 1900, 726.)
Rods: 1.0 by 2 to 4 microns, occurring singly and in chains. Motile with peritrichous flagella. Spores central, 1.0 by 1.25 microns. Gram-positive.
Gelatin colonies: White to bluish, translucent.
Gelatin stab: White, translucent surface growth. Slight liquefaction.
Agar colonies.
Agar slant: Whitish-gray, moist, lobed, fringed.
Broth: Turbid, with slight, grayish sediment.
Litmus milk: Slightly alkaline.
Potato: Colorless, smooth, glistening, becoming slimy, flesh-colored to brownish.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Blood serum not liquefied.

Ferments urea to ammonium carbonate.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil.

32. **Bacillus ruminatus** Gottheil. (Cent. f. Bakt., II Abt., *7*, 1901, 490.)

Gottheil (*loc. cit.*) gives the following as a possible synonym: *Bacterium perittomaticum* Burchard, Arb. aus dem bakt. Inst. der techn. Hochsch. z. Karlsruhe, *2*, 1902, 11.

Rods: 0.3 to 1.5 by 5 microns, occurring singly, in pairs and short chains. Motile with peritrichous flagella. Spores central, 0.8 to 1.0 by 1.5 to 1.7 microns. Gram-positive. Cells store fat as reserve material.

Gelatin colonies: Circular, white, homogeneous, entire.
Gelatin stab: Liquefaction infundibuliform.
Agar colonies: Circular to spreading, white, moist, opaque, raised, glistening.
Agar slant: Whitish, slimy, raised, glistening, becoming yellowish to brownish.
Broth: Turbid, with fragile pellicle, becoming clear.
Litmus milk: Slightly acid; coagulated; peptonized.
Potato: Whitish, homogeneous, glistening.
Indol not formed.
Nitrates are reduced.
Acid in dextrose, lactose and sucrose.
Starch is hydrolyzed.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 37°C. Will grow at 45° to 50°C.
Habitat: Soil.

33. **Bacillus danicus** Löhnis and Westermann. (Cent. f. Bakt., II Abt., *22*, 1908, 253.)

Rods: 2 to 3 by 4 to 8 microns, occurring singly and in chains. Motile with peritrichous flagella. Spores central. Gram-positive.

Gelatin colonies: Circular, flat, grayish-white, glistening.
Gelatin stab: Liquefaction infundibuliform.
Agar colonies: Circular, slightly raised, whitish-gray, glistening, slightly translucent.
Agar slant: Grayish-white, glistening, flat, spreading, becoming reddish-gray in thicker portions.
Broth: Clear, with slight slimy sediment.
Litmus milk: Slow coagulation. Slow peptonization.
Potato: Abundant, yellowish-white, folded, silky, glistening, spreading.
Indol not formed.
Nitrates not reduced.
Starch hydrolyzed.
Blood serum not liquefied.

Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

34. **Bacillus silvaticus** Neide. (Cent. f. Bakt., II Abt., *12*, 1904, 25.)

Neide, Cent. f. Bakt., II Abt., *12*, 1904, 25, gives the following as a possible synonym:

Bacillus hessii (Guillebeau) Kruse, Flügge, Die Mikroorganismen, *2*, 1896, 210.

Rods: 0.2 to 1.6 by 3.25 microns, occurring singly, in pairs and short chains. Motile with peritrichous flagella. Spores central, 1.0 by 1.7 microns. Gram-positive. Cells store fat as reserve material.

Gelatin colonies: Small, whitish, entire.
Gelatin stab: Liquefaction saccate.
Agar colonies: Soft, slimy, circular, grayish, turning yellowish-brown.
Agar slant: Grayish, translucent, spreading.
Broth: Slightly turbid, becoming clear. Grayish, slimy sediment.
Litmus milk: Acid; coagulated; peptonized.
Potato: Grayish, slimy, spreading.
Indol not formed.
Nitrates not reduced.
Starch is hydrolyzed.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 35°C. Will grow at 45° to 50°C.
Habitat: Soil.

35. **Bacillus psychrocartericus** (Rubentschick) Bergey et al. (*Urobacillus psychrocartericus* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 166; ibid., *66*, 1925–1926, 161; ibid., *67*, 1926, 167; ibid., *68*, 1926, 161; ibid., *68*, 1926, 327; Bergey et al., Manual, 3rd ed., 1930, 403.)

Rods: 0.7 to 0.8 by 1.0 to 1.2 microns, occurring singly and in pairs. and in short chains. Spores central. Motile. Gram-positive.

Urea gelatin colonies: Grayish-white.
Urea gelatin stab: No liquefaction.
Urea agar slant: Grayish-white layer.
Urea broth: Turbid, becoming clear.
Urea milk: Peptonization.
Urea potato: Slight grayish streak.
Indol not formed.
Nitrates reduced to nitrites
H_2S not formed.
Ammonia not formed
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Sewage slime.

36. **Bacillus aminovorans** den Dooren de Jong. (Cent. f. Bakt., II Abt., *71*, 1927, 215.)

Rods: Spores are formed. Motile with peritrichous flagella. Gram-positive.

Agar colonies: Colorless.

Amino-agar colonies: Colorless.

Disintegrate the following organic acids: Acetic, glycollic, lactic, glycerinic, formic, fumaric, malic, citric, sarcosin, betain, tyrosin, propionamid, lactamid, uric.

Disintegrate the following amino compounds: Methylamin, trimethylamin, butylamin, ethanolamin, cholin, glucosamin.

Attack dextrose and ethyl alcohol.

Other carbohydrates not attacked.

Catalase is formed.

Urease not formed.

Disintegrate trimethylamine.

Aerobic, facultative.

Optimum temperature 25° to 30°C.

Habitat: Soil.

37. **Bacillus hesmogenes** (Rubentschick) Bergey et al. (*Urobacillus hesmogenes* Rubentschick, Cent. f. Bakt., II Abt., *64*, 1925, 166; ibid., *66*, 1925–1926, 161; ibid., *68*, 1926, 161 Bergey et al., Manual, 3rd ed., 1930, 404.)

Rods: 0.8 to 0.9 by 2.5 to 6.5 microns, occurring singly and in pairs. Spores. Motile. Gram-positive.

Urea gelatin colonies: Circular, gray, forming daughter colonies along the periphery.

Urea gelatin stab: No liquefaction.

Urea agar colonies.

Urea agar slant: Grayish-white, thin, smooth, entire.

Urea broth: Turbid, becoming clear.

Urea milk: Unchanged.

Urea potato: Dirty-gray streak.

Indol not formed.

Nitrates reduced to nitrites.

H_2S not formed.

Ammonia not formed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Sewage slime.

38. **Bacillus vulgatus** Trevisan. (I Gen. e Spec. d. Batteriacee, 1889, 19; *Bacillus mesentericus vulgatus* Flügge, Die Mikroorganismen, 1886, 322.)

Rods: 0.5 by 2.0 to 3.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.5 by 1.2 microns. Gram-positive.

Gelatin colonies: Circular, homogeneous, refractive.

Gelatin stab: Liquefaction crateriform.

Agar colonies: Circular, grayish, refractive, irregular to entire.

Agar slant: Moist, white or cream-white, slightly spreading, slightly raised. Non-adherent.

Broth: Turbid, with thin gray pellicle, becoming clear.

Litmus milk: Soft coagulum. Peptonization.

Potato: Thick, white to pink, deeply wrinkled, folded, becoming brownish.

Indol not formed.

Nitrates not reduced.

Acid in dextrose and sucrose.

Blood serum shows slight liquefaction.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

39. **Bacillus mesentericus** Trevisan. (I Gen. e Spec. d. Batteriacee, 1889, 19; *Bacillus mesentericus fuscus* Flügge, Die Mikroorganismen, 1886, 321.)

Rods: 0.8 by 1.5 to 4.0 microns, occurring singly and in pairs. Some show capsule on albuminous media. Motile with peritrichous flagella. Spores central, 0.5 by 1.125 microns. Shows capsule in albuminous media. Gram-positive.

Gelatin colonies: Circular, grayish, granular margin.

Gelatin stab: Liquefaction crateriform, becoming stratiform.

Agar colonies: Circular, refractive, spreading, entire.

Agar slant: Soft, white to cream-white, somewhat translucent, serrate. Non-adherent.

Broth: Turbid, with fragile pellicle, becoming clear.

Litmus milk: No coagulation; peptonization.

Potato: Moist, brown, finely wrinkled.

Indol not formed.

Nitrates not reduced.

Acid in dextrose and sucrose.

Blood serum shows slight liquefaction in 10 days.

H_2S formation (slight).

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

39A. **Bacillus mesentericus** var. **flavus** Laubach. (Jour. Bact., *1*, 1916, 497; *Bacillus flavus* Bergey et al., Manual, 1st. ed., 1923, 286; not *Bacillus flavus* Fuhrmann, Cent. f. Bakt., II Abt., *19*, 1907, 117.)

This organism varies from *Bacillus mesentericus* in its failure to act on milk, does not grow on potato, and produces a yellow growth on gelatin and agar media.

40. **Bacillus pumilus** Gottheil. (Cent. f. Bakt., II Abt., *7*, 1901, 681.)

Gottheil (*loc. cit.*) gives the following as a possible synonym: *Bacillus leptodermis* Burchard, Arb. a. d. bakt. Institut der techn. Hochschule zu Karlsruhe, *2*, 1902, 33.

Rods: 0.4 by 2.0 to 3.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.5 to 0.9 by 1.5 microns. Gram-positive. No reserve materials demonstrated.

Gelatin colonies: Small, whitish, homogeneous, entire.

Gelatin stab: Spreading surface growth. Liquefaction crateriform.

Agar colonies.

Agar slant: Thin, whitish, glistening, adherent.

Broth: Turbid, with thin pellicle.

Litmus milk: Not coagulated; peptonized.

Potato.

Indol not formed.

Nitrates not reduced.

Starch is hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 37°C. Will grow at 45° to 50°C.

Habitat: Soil.

41. **Bacillus brevis** Migula. (Bacillus No. 1, Flügge, Zeit. f. Hyg., *17*, 1894, 294; Migula, System der Bakterien, 1900, 583.)

Rods: 0.375 to 0.5 by 2.0 to 3.0 microns, with pointed ends, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.75 by 1.25 to 1.5 microns. Gram-positive.

Gelatin colonies: Grayish, with dark center and ciliate margin.

Gelatin stab: Liquefaction crateriform to infundibuliform.

Agar colonies: Circular, thin, translucent, spreading, entire.

Agar slant: Thick, white, moist, spreading with silvery sheen.

Broth: Turbid, with heavy pellicle and flocculent sediment.

Litmus milk: No coagulation. Peptonization. Litmus reduced.

Potato: Scant, moist, yellow to yellow-brown.

Indol not formed.

Nitrates not reduced.

Acid in none of the carbohydrate media.

Starch is hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Soil.

42. **Bacillus lacticola** (Migula) Neide. (*Bacterium lacticola* Migula, System der Bakterien, 1900, 305; Neide, Cent. f. Bakt., II Abt., *12*, 1904, 168.)

Neide (*loc. cit.*) gives the following as possible synonyms:

Bacillus lactis v Flügge, Die Aufgaben und Leistungen der Milchsterilisierung, Zeitschr. f. Hyg., *17*, 1894, 299; *Bacillus geniosporus* Burchard, Arb. aus d. Bakt. Inst. d. techn. Hochsch. Karlsruhe, *2*, 1902, 14; *Bacillus lacteus* Lembke, Weiterer Beitrag zur Bakterienflore d. Darmes, Arch. f. Hyg., *29*, 1897, 323; *Bacillus aureus* Pansini, Bakt. Studien über den Auswurf, Virchow's Archiv., *22*, 1890, 436; *Bacillus butyricus* Hueppe, Mitteil. a. d. Kaiserl. Gesundheitsamte, *2*, 1884, 309.

Rods: 1.0 to 1.2 by 2.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.6 to 1.0 by 1.4 to 2.6 microns. Gram-positive. Cells store fat and volutin as reserve material.

Gelatin colonies.

Gelatin stab: Whitish surface growth. Liquefaction crateriform to saccate.

Agar colonies.

Agar slant: Grayish, dry, homogeneous, smooth, becoming glistening, tenacious, with fimbriate margin.

Broth: Turbid.

Litmus milk: Not coagulated; peptonized.

Potato: Grayish-violet, spreading, becoming yellowish.

Indol not formed.

Nitrates not reduced.

Starch slightly hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 37°C. Will grow at 40° to 45°C.

Habitat: Soil.

43. **Bacillus teres** Neide. (Cent. f. Bakt., II Abt., *12*, 1904, 161.)

Neide (*loc. cit.*) gives the following as possible synonyms:

Bacillus globigii, synonymous with *Bacillus mesentericus ruber* Globig, Zeitschr. f. Hyg., 1888, *3*, 323; Tataroff, Die Dorpater Wasserbakterien, Inaugural Diss., Dorpat, 1891, 21; *Bacillus albolactis*, synonymous with *Bacillus lactis albus* Löffler, Berliner Klinische Wochenschr., 1887, 630; *Bacterium tomentosum* Henrici, arb. a. d. Bakt. Inst. d. techn. Hochsch. Karlsruhe, *1*, 1901, 40; *Bacterium filiforme* Migula, synonymous with *Bacillus filiformis* Tils, Zeitschr. f. Hyg., *9*, 1890, 294; *Bacterium pansinii*, synonymous with *Bacillus No. 3*, Pansini, Bakt. Studien über den Auswurf, Virchow's Archiv, *122*, 1890, 439.

Rods: 0.9 to 1.2 by 2.0 microns, occurring singly, in pairs and short chains. Motile with peritrichous flagella. Spores central, 0.8 to 1.2 by 1.2 to 2.0 microns. Gram-positive. Cells store glycogen as reserve material.

Gelatin stab: Grayish-white surface growth. Liquefaction stratiform.

Agar colonies: Bluish-gray, finely granular.

Agar slant: Grayish to white, glistening, slightly wrinkled.

Broth: Turbid with heavy sediment.

Litmus milk: Not coagulated; peptonized.
Potato: Light brown, dry, uneven growth covering surface after 14 days.
Indol not formed.
Nitrates not reduced.
Starch is hydrolyzed.
Blood serum liquefied.
Aerobic, facultative.
Optimum temperature 30°C. Will grow at 35° to 40°C.
Habitat: Soil. Also isolated from milk.

44. **Bacillus agri** Laubach and Rice. (Jour. of Bact., *1*, 1916, 516.)
Rods: 0.625 to 0.75 by 2.5 to 5.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.625 to 1.125 by 1.25 microns. Gram-positive.
Gelatin colonies: Circular, grayish, moist, raised, opaque, glistening.
Gelatin stab: Liquefaction infundibuliform.
Agar colonies: Small, gray, moist, raised, glistening, ciliate.
Agar slant: Gray, smooth, moist, opaque, glistening.
Broth: Turbid, with gray sediment.
Litmus milk: Peptonized; litmus reduced.
Potato: Gray, moist, raised, viscid.
Indol not formed.
Nitrates not reduced.
Acid in none of the carbohydrate-media.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil.

45. **Bacillus parvus** Neide. (Cent. f. Bakt., II Abt., *12*, 1904, 344.)
Neide (*loc. cit.*) gives the following as possible synonyms:
Bacillus leptodermis Burchard, Arbeiten aus d. bakt. Inst. d. techn. Hochsch. zu Karlsruhe, *2*, 1902, 33; *Bacillus laevis* Grace and Percy Frankland, Philos. Transact. of the Royal Society of London, *178*, B, 1887, 278; *Bacillus coccoideus*, synonymous with *Bacillus No. 6*, Pansini, Bakteriol. Studien über den Auswurf, Virchow's Archiv., *122*, 1890, 422; *Bacillus geniculatus* W. de Bary, Beitrag zur Kentniss der niederen Organismen im Mageninhalt, Inaugural Diss. Strasburg, Leipzig, 1885; *Bacillus leptosporus* L. Klein, Cent. f. Bakt., *6*, 1889; *Bacillus tenuis* Duclaux, Le Lait, 1889; *Bacillus intermedius*, synonymous with *Bacillus lactis x*, Flügge, Zeitschr. f. Hyg., *17*, 1894, 296.
Rods: 0.4 to 0.7 by 1.8 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.35 to 0.4 by 1.0 to 1.2 microns. Gram-positive. Cells store no reserve material.
Gelatin colonies: Very small, not visible to naked eye.
Gelatin stab: Small, grayish-white surface growth. Fimbriate growth in stab. Slow, stratiform liquefaction.

Agar colonies: Yellowish-white, becoming yellow, homogeneous, glistening.

Agar slant: Yellowish-white, spreading, homogeneous, glistening, wrinkled, fimbriate.

Broth: Turbid.

Litmus milk: Not coagulated; peptonized.

Potato: Yellowish-white, soft, translucent, glistening.

Indol not formed.

Nitrates not reduced.

Starch is hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 37°C. Will grow at 50° to 55°C.

Habitat: Soil. Also isolated from horse dung.

46. **Bacillus globigii** Migula. (Kartoffel-bacillus, Globig, Zeitschr. f. Hyg., *3*, 1888, 323; *Bacillus mesentericus ruber* Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 199; Migula, System der Bakterien, 1900, 554.)

Rods: 0.5 by 2.0 to 3.0 microns, occurring singly and in short chains. Motile with peritrichous flagella. Spores central, 0.5 by 1.25 microns. Gram-positive.

Gelatin colonies: Small, circular, grayish, slightly granular.

Gelatin stab: Slight surface growth. Liquefaction stratiform.

Agar colonies: Soft, white, ameboid, spreading.

Corn mash agar colonies: Pink colonies develop.

Agar slant: Thin, yellowish-white, soft, spreading.

Broth: Slightly turbid, with flocculent sediment.

Litmus milk: Slight acidity; slow peptonization.

Potato: Yellow, moist, becoming reddish-brown.

Indol not formed.

Nitrates not reduced.

Dextrose and xylose are attacked. Ethyl alcohol and acetone are formed.

Starch is hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

47. **Bacillus fusiformis** Gottheil. (Cent. f. Bakt., II Abt., *6*, 1901, 724.)

Rods: 0.8 by 3.0 to 5.0 microns, occurring singly, in pairs and short chains. Motile with peritrichous flagella. Spores, spherical, central, 1.0 micron in diameter. Gram-positive. Cells store volutin as reserve material.

Gelatin colonies: Very small, circular, homogeneous.

Gelatin stab: Liquefaction infundibuliform.

Agar colonies: Circular, thick, white, opaque, spreading, filamentous.

Agar slant: White, glistening, membranous, becoming cream-color to yellow.

Broth: Turbid, with gray sediment.

Litmus milk: No coagulation. Peptonized. Litmus reduced.

Potato: Slight, yellow growth, becoming yellowish-brown.

Indol is formed (trace).

Nitrates not reduced.

Acid in none of the carbohydrate media.

Starch not hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 35°C. Will grow at 40° to 45°C.

Habitat: Soil.

48. **Bacillus sphaericus** Neide. (Cent. f. Bakt., II Abt., *12*, 1904, 350.)

Neide (*loc. cit.*) gives the following as possible synonyms:

Plectridium palludosum Fischer, Vorlesungen über Bakt., 1897, 20; *Bacillus gracilis* Zimmermann, Die Bakterien unserer Nutz. u. Trinkwässer, inbesordere des Wassers der Chemnitzer Wasserleitung, 1890; *Bacillus butyricus* Bottein, Zeitschr. f. Hyg., *11*, 1892, 421; *Bacillus pseudotetanicus* Kruse, in Flügge, Die Mikroorganismen, 1896, *2*, 267; *Bacillus pseudotetani* Tavel, Cent. f. Bakt., I Abt., *23*, 1898, 538; *Bacillus (Streptobacter) albuminus* Schroeter, Kryptogamenflora von Schlesien, *3*, 1, 1886, 162; *Bacillus putrificus coli* Flügge, Die Mikroorganismen, 1886, 303; *Bacillus thalassophilus* Russell, Zeitschr. f. Hyg., *11*, 1892, 190.

Rods: 0.9 to 1.3 by 3.5 to 3.8 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores spherical, central, 1.2 to 1.5 microns in diameter. Gram-positive. Cells store volutin as reserve material.

Gelatin colonies: Small, barely visible, circular.

Gelatin stab: Slight surface growth. Small, yellowish colonies in stab, becoming arborescent. No liquefaction.

Agar colonies: Small, clear, transparent, becoming yellowish-brown.

Agar slant: Thin, transparent layer, becoming yellowish-brown.

Broth: Turbid.

Litmus milk.

Potato: Thin, grayish layer. Slow development.

Indol not formed.

Nitrates not reduced.

Starch not hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 35°C. Will grow at 45° to 50°C.

Habitat: Soil.

49. **Bacillus morulans** Boncquet. (Phytopathology, *7*, 1917, 269.)

Rods: 0.9 to 1.5 by 1.5 to 2.0 microns, occurring singly and in pairs. Spores. Motile with four, long peritrichous flagella. Gram-negative.

Gelatin colonies: Circular to irregular, flat to convex contoured, amoeboid, transparent, viscous.

Gelatin stab: Light orange surface growth. No liquefaction.

Agar colonies.

Agar slant.

Broth.

Litmus milk: Peptonized. Alkaline.

Potato: Yellow, glistening.

Indol not produced.

Nitrates are reduced.

Acid in dextrose, levulose, galactose, maltose, sucrose, salicin, mannitol and isodulcitol. No gas in carbohydrate media.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Associated with curly top of sugar beet.

50. **Bacillus aterrimus** Lehmann u. Neumann. (Atlas u. Grund. d. Bakt., 1 Aufl., 1896, 303.)

Rods: 0.5 by 2.0 to 3.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.5 by 1.5 microns. Gram-positive.

Gelatin stab: Rapid, crateriform liquefaction.

Agar colonies: Circular, flat, amorphous, butyrous, medium darkened.

Broth: Moderate turbidity with flocculent sediment.

Litmus milk: Slight alkalinity, with slow peptonization. Litmus reduced in 10 to 20 days.

Potato: Abundant, creamy, with pink or brownish areas. Medium darkened.

Indol not formed.

Nitrates not reduced.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

51. **Bacillus niger** Migula. (*Bacillus lactis niger* Gorini, Giornale della Reala Societa Italica d. Igiene, *16*, 1894; Migula, System der Bakterien, 1900, 636.)

Rods: 0.375 to 0.75 by 1.5 to 3.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.75 to 1.0 by 1.125 to 1.25 microns. Gram-positive.

Gelatin stab: Liquefied.

Agar colonies: Circular, raised, amorphous, with undulate margin.

Agar slant: Moderate, raised, smooth, butyrous; the medium becoming brown.

Broth: Turbid with heavy ring at surface and moderate, viscid sediment.

Litmus milk: Becoming alkaline. Slowly digested. Litmus reduced in 10 days.

Potato: Abundant, smooth, becoming wrinkled. Medium darkened.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, lactose, sucrose and glycerol.
Blood serum liquefied in 5 days.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil.

52. **Bacillus pandora** Corbet. (Jour. of Bact., *19*, 1930, 321.)

Rods, 0.5 to 1.0 by 2.0 microns. Chains. Motile with peritrichous flagella. Gram-positive. Encapsulated. Spores oval, terminal of greater diameter than the rods.

Gelatin stab: Liquefied.
Agar colonies: Punctiform, smooth, white, irregular margin, dull.
Agar slant: Opaque, gray, dull, smooth.
Broth: Turbid.
Litmus milk: Acid, coagulated.
Potato:
Indol is formed.
Nitrates are reduced.
Ammonia is formed.
Starch is not hydrolyzed.
Acid and gas in lactose and sucrose, and latex carbohydrate.
Acid in dextrose.
H_2S is not formed.
Egg albumin is digested.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Found in latex of Hevea Brasiliensis.

53. **Bacillus terminalis** Migula. (System der Bakterien, 1900, 578; *Bacillus badus* Batchelor, Jour. of Bact., *4*, 1919, 23.)

Rods: 0.375 by 2.25 to 4.0 microns, occurring singly and in chains. Motile with peritrichous flagella. Spores terminal, 0.75 by 1.5 microns. Gram-positive.

Gelatin colonies: Concentric formation, margin entire.
Gelatin stab: Liquefaction crateriform.
Agar colonies: Small, circular, grayish, entire.
Agar slant: Thin, spreading, smooth, moist, glistening. The medium becoming darker.
Broth: Slightly turbid.
Litmus milk: Unchanged.
Potato: Usually no growth.
Indol not formed.
Nitrates not reduced.
Acid in none of the carbohydrate media.

Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil.

53A. *Bacillus terminalis* var. *thermophilus* Prickett. (Tech. Bul. No. 147, New York Agr. Exp. Sta., 1928.)

The characteristics of this organism are the same as for *Bacillus terminalis* Migula, with the exceptions that this organism produces a brown, water soluble pigment on agar and its optimum temperature is 55° to 65°C. while that of *Bacillus terminalis* is given as 30°C.

54. **Bacillus serositidis** Lacoste (Memorias do Institute Oswaldos Cruz, *26*, 1932, 1).

Rods: 0.1 to 1.1 by 1.5 to 3.0 microns, with rounded ends, occurring singly and in short chains. Polar metachromatic granules are formed. Motile with one polar flagellum, occasionally two or three flagella, are seen. Spores, 0.5 to 0.8 microns, sub-terminal, of greater diameter than the rods. Generally Gram variable.

Gelatin colonies: Translucent, with irregular margin with darker center. Liquefaction after 48 hours.

Gelatin stab: Crateriform liquefaction, becoming stratiform.

Agar colonies: Small, circular, raised, translucent, with darker center, and irregular margin.

Agar slant: Translucent, becoming whitish and slimy.

Broth: Flocculi and streamers in the clear fluid.

Litmus milk: Litmus reduced becoming dark-brown in color.

Potato: No visible growth.

Indol is not formed.

Nitrates are not reduced.

None of the carbohydrates are fermented.

Loeffler's blood serum is not liquefied.

Aerobic.

Optimum temperature 37 to 40°C.

Habitat: Isolated from pus from patient dying of fibro-purulent inflammation of the pericardium, pleura and peritoneum.

55. **Bacillus asterosporus** (Meyer) Migula. (*Astasia asterospora* Meyer, Sitzungsbricht d. Gesellsch. z. Beförd. d. gesamt. naturwissensch., Marburg, 1897; Migula, System der Bakterien, 1900, 528.)

Gottheil, Cent. f. Bakt., II Abt., *7*, 1901, 727, gives the following as possible synonyms:

Bacillus subanaerobicus Gruber, Cent. f. Bakt., *1*, 1887, 71; *Bacillus thalassophilus* Russell, Zeitschr. f. Hyg., *11*, 1892, 190.

Rods: 1.0 to 1.2 by 3.0 to 6.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores terminal, 1.0 to 1.5 by 1.7 to 2.5 microns, star-shaped on cross section. Gram-positive. Cells store glycogen and volutin as reserve materials.

Gelatin stab: Liquefaction infundibuliform.
Agar colonies: Slightly raised, circular to irregular, yellow, concentric.
Agar slant: Thin, transparent to yellowish-white layer.
Broth: Turbid.
Litmus milk: Coagulated, acid; slowly peptonized.
Potato: White, raised, glistening, with gas bubbles.
Indol not formed.
Nitrates are reduced.
Acid and gas in dextrose, lactose and sucrose.
Starch is hydrolyzed.
Blood serum not liquefied.
Capable of fixing atmospheric nitrogen.
Aerobic, facultative.
Optimum temperature 30°C.
Habitat: Soil.

56. **Bacillus novus** Huss. (Cent. f. Bakt., II Abt., *19*, 1907, 256.)

Rods: 0.6 to 0.7 by 2.0 to 7.0 microns, occurring singly. Motile with peritrichous flagella. Spores terminal, 0.9 to 1.0 by 1.3 to 1.75 microns. Gram-positive.

Gelatin colonies: Colorless to light yellowish, glistening.
Gelatin stab: Slight, grayish surface growth. Liquefaction infundibuliform.
Agar colonies: Circular, flat, smooth, grayish, glistening.
Agar slant: Thin, bluish-gray, glistening, slightly granular, lobed.
Broth: Slightly turbid, with slimy sediment.
Litmus milk: Acid; coagulated.
Potato: Thin, white, smooth, glistening.
Indol not formed.
Nitrates not reduced.
Blood serum not liquefied.
Starch.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from "sterilized" milk.

57. **Bacillus macerans** Schardinger. (Cent. f. Bakt., II Abt., *14*, 1904, 772.)

Rods: 0.8 to 1.0 by 4.0 to 6.0 microns, occurring singly and in pairs. Motile with polar flagella. Spores terminal, 1.5 by 2.0 microns. Gram-positive.

Gelatin colonies: Small, white.
Gelatin stab: Slight surface growth. No liquefaction.
Agar colonies: Gray, circular, contoured.
Agar slant: Barely visible, colorless growth.
Broth: Turbid, with slimy sediment.
Litmus milk: Coagulated with gas formation.

Potato: Rapid, heavy growth, with gas formation.
Indol not formed.
Nitrates not reduced.
Acid formed in dextrose, lactose, maltose, mannose, arabinose, inulin and starch.
Starch is hydrolyzed to dextrose.
Forms acetone in media containing vegetable matter.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from vats in which flax is subjected to retting process.

58. **Bacillus lautus** Batchelor. (Jour. of Bact., *4*, 1919, 30.)
Rods: 1.5 by 2.25 to 4.5 microns, with rounded ends. Motile. Spores terminal, 1.875 by 3.0 microns. Gram-positive.
Gelatin colonies: Small, white, irregular margin.
Gelatin stab: No liquefaction.
Agar colonies: Very small, white, circular, irregular.
Agar slant: Thin, dry, transparent, layer.
Broth: Turbid, with flocculent sediment.
Litmus milk: Acid; litmus reduced.
Potato: Faint, moist, pale brown streak.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, lactose and sucrose.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal of infants.

59. **Bacillus tritus** Batchelor. (Jour. of Bact., *4*, 1919, 29.)
Rods: 0.75 by 3.75 microns, with rounded ends, occurring singly. Spores terminal, 1.125 by 1.5 microns. Motile. Gram-positive.
Gelatin colonies: Brown, homogeneous, entire.
Gelatin slant: No liquefaction.
Agar colonies: Moist, opaque, circular, irregular, with fimbriate margin
Agar slant: Thick, creamy, moist, becoming buff in color.
Broth: Turbid, with fragile pellicle and gray, granular sediment.
Litmus milk: Unchanged.
Potato: Faint, brown growth.
Indol not formed.
Nitrates not reduced.
No acid formed in carbohydrate media.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal of infants.

60. **Bacillus lactimorbus** Jordan and Harris. (Jour. Amer. Med. Assn., *50*, 1908, 1669; Jour. of Infect. Dis., *6*, 1909, 465.)

Rods, of variable size and shape, showing metachromatic granules. Spores oval, terminal causing bulging of the cell Motile possessing peritrichous flagella. Gram-positive.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Gray, circular, flat, undulate.

Agar slant: Abundant, gray, spreading, flat, glistening, smooth, butyrous, becoming yellowish.

Broth: Turbid, with gray pellicle and sediment.

Litmus milk: Alkaline; peptonized.

Potato.

Indol not formed.

Nitrates not reduced.

Starch not hydrolyzed.

Löffler's blood serum, not liquefied

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Soil, hay, etc.

61. **Bacillus imminutus** McBeth. (Soil Science, *1*, 1916, 455.)

Rods: 0.2 by 1.5 microns, occurring singly. Motile with one to five peritrichous flagella. Spores spherical, terminal, 0.5 micron in diameter. Gram-positive.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Cellulose agar colonies: Circular, concave, vitreous, becoming light, transparent yellow, homogeneous, entire.

Agar slant: No growth.

Broth: No growth.

Litmus milk: Unchanged.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

No ammonia produced.

Acid formed in none of the carbohydrate media.

Starch not hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

62. **Bacillus pseudotetanicus** Kruse. (Anaërobier Nr. IX, Sanfelice, Ztschr. f. Hyg., *14*, 1893, 375; Kruse, in Flügge, Die Mikroorganismen, *2*, 1896, 267; *Bacillus pseudotetanicus aerobinus* Migula, System der Bacterien, 1900, 626.)

Rods: 0.75 by 1.5 to 3.0 microns, occurring singly. Motile with peritrichous flagella. Spores spherical, terminal, 1.0 to 1.25 microns in diameter. Gram-positive.

Gelatin colonies: Small, pale yellow, becoming dense and opaque.

Gelatin stab: Slightly spreading surface. Growth sometimes arborescent in stab. Slow liquefaction (12 days).

Agar colonies: Circular to amoeboid, becoming thick, dense, yellowish-white.

Agar slant: Thin, translucent, moist, becoming pale, yellowish-white.

Broth: Turbid, with slight sediment.

Litmus milk: No coagulation. Gradual reduction of litmus. No peptonization.

Potato: Scanty, moist, yellowish, becoming brown

Indol not formed.

Nitrates reduced.

Acid in none of the carbohydrate media.

Blood serum slowly liquefied (13 days).

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

63. **Bacillus circulans** Jordan. (Report, Mass. State Board of Health, 1890, 831.)

Rods: 0.5 by 2.5 to 4.0 microns, occurring singly. Motile with peritrichous flagella. Spores terminal, 0.75 by 1.125 microns. Gram-positive.

Gelatin colonies: Small, circular to amoeboid, fimbriate.

Gelatin stab: Little or no surface growth. No liquefaction.

Agar colonies: Circular, white to pale yellow, entire to serrate.

Agar slant: Slight, pale white, moist streak.

Broth: Slightly turbid.

Litmus milk: Slightly acid. Slowly coagulated. Litmus reduced.

Potato: No visible growth.

Indol not formed.

Nitrates not reduced.

Acid in dextrose, lactose and sucrose.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

64. **Bacillus esterificans** (Maassen) Lehmann and Neumann. (*Bacterium esterificans* Maassen, Arbeiten a. d. Kaiserl. Gesundheitsamte, *15*, 1899; Lehmann and Neumann, Atlas u. Grund. d. Bakt., 5 Aufl., 1912, 463.)

Rods: 0.5 to 0.7 by 1.4 to 5.2 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores terminal, 1.2 to 1.4 by 2.7 to 3.15 microns. Volutin stored as reserve material. Gram-positive.

Gelatin colonies: Small, yellowish, glistening.

Gelatin stab: No surface growth. No liquefaction.
Agar colonies: Gray, flat, lobed.
Agar slant: Translucent, bluish-gray, glistening, granular.
Broth: Slightly turbid, with slight sediment.
Litmus milk: Slight coagulation.
Potato: Thin, whitish, glistening.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, lactose, sucrose, raffinose, arabinose, xylose and mannitol.
Starch not hydrolyzed.
H_2S is formed.
Cultures have an agreeable odor on all media.
Blood serum not liquefied.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Found in a solution of litmus undergoing decomposition. Also isolated from butter.

65. **Bacillus flexus** Batchelor. (Jour. of Bact., *4*, 1919, 32.)
Rods: 1.5 to 1.825 by 2.25 to 4.5 microns, with square ends, occurring singly, in pairs and in chains. Spores central, 1.25 by 1.5. Motile. Gram-positive.
Gelatin colonies: Circular-irregular, homogeneous, entire.
Gelatin stab: Infundibuliform liquefaction.
Agar colonies: Dirty-white, circular-irregular.
Agar slant: Slight, gray, filiform.
Broth: Turbid with flocculent sediment.
Litmus milk: Acid; coagulated.
Potato: Raised, cream-colored, abundant.
Indol.
Nitrates.
Acid in dextrose and lactose.
Blood serum slowly liquefied.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Intestinal canal of infants.

66. **Bacillus pabuli** Schieblich (Cent. f. Bakt., II Abt., *58*, 1923, 204.)
Rods with rounded ends, 0.7 to 0.8 by 2.0 to 5.0 microns, occurring singly. Motile, with peritrichous flagella. Spores terminal. Gram-positive.
Gelatin colonies: Whitish-gray, butyrous, granular.
Gelatin stab: Whitish-gray surface growth. Liquefaction crateriform.
Agar colonies: Small, circular, grayish-white, raised, glistening.
Agar slant: Butyrous, transparent, spreading, adherent.
Broth: Slightly turbid, with slight grayish sediment.

Litmus milk: Unchanged.
Potato: Butyrous, spreading.
Indol formed in small amounts.
Nitrates.
Carbohydrates unchanged.
H_2S not formed.
Aerobic, facultative.
Optimum temperature 35°C.
Habitat: Isolated from green fodder.

67. **Bacillus sublustris** Schieblich (Cent. f. Bakt., II Abt., *58*, 1923, 206.)

Rods with rounded ends, 0.7 to 1.0 by 0.8 to 5.0 microns occurring singly and in pairs. Motile with peritrichous flagella. Spores terminal. Gram-positive.

Gelatin colonies: Small, circular, raised, grayish-white to grayish-brown, glistening.

Gelatin stab: Slight, grayish-white surface growth. No liquefaction.

Agar colonies: Small, circular, raised, glistening, grayish-white to grayish-brown.

Agar slant: Abundant, flat, glistening, spreading.
Broth: Turbid, with slight grayish sediment.
Litmus milk: Unchanged.
Potato: Very slight, flat, glistening, streak.
Marked indol formation.
Nitrates.
Carbohydrates unchanged.
Small amounts of H_2S formed.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from green fodder.

68. **Bacillus anthracis** Cohn *emend.* Koch. (Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft II, 1872, 177; Koch, *ibid.*, *2*, Heft II, 1876, 279; Les infusories de la maladie charbonneuse Davaine, Compt. rend. Acad. Sci., Paris, *69*, 1864, 393; Bactéridie des charbon, Pasteur and Joubert, Compt. rend. Acad. Sci., Paris, *84*, 1877, 900; *Bacillus* (*Streptobacter*) *anthracis* Schroeter, Kryptogamenflora v. Schlesien, *3*, 1, 1886, 163; *Pollendera anthracis* Trevisan see DeToni and Trevisan in Saccardo, Sylloge Fungorum, *8*, 1889, 956; *Bacterium anthracis* Migula in Engler and Prantl, Die natürlichen Pflanzenfam., 1 Teil, *1*, 1a, 1895, 21; *Aplanobacter anthracis* Er. Smith, Bacteria in Relation to Plant Diseases, 1905, 171; *Bacillus* (*Bacteridium*) *anthracis* Buchanan, Jour. Bact., *3*, 1918, 37.)

Rods: 1.0 to 1.25 by 5 to 10 microns with square to concave ends, occurring in long chains. In broth long, flexible filaments are formed, 1.0 to 2.0 microns in width. Capsules are formed. Non-motile. Spores central, 0.7 to 0.8 by 1.5 to 1.75 microns. Gram-positive.

Gelatin colonies: Grayish-white, fringed.

Gelatin stab: Arborescent growth in stab. Liquefaction crateriform, becoming stratiform.

Agar colonies: Irregular, fringed, made up of interlacing chains which lie parallel along the margin.

Agar slant: Grayish, tough, spreading, fimbriate.

Broth: Flocculent turbidity, thick pellicle and yellowish sediment.

Litmus milk: Somewhat acid; coagulated; peptonized.

Potato: White to creamy, spreading.

Indol not formed.

Nitrates not reduced.

Acid in dextrose.

Starch not hydrolyzed.

Blood serum is partly liquefied.

Aerobic, facultative.

Optimum temperature 37° to 38°C.

Habitat: The cause of anthrax in man, cattle, swine and sheep. Pathogenic for mice, guinea pigs and rabbits.

69. **Bacillus panis** Migula. (*Bacillus mesentericus panis viscosus II* Vogel, Zeitschr. f. Hyg., *26*, 1897, 404; Migula, System der Bakterien, 1900, 576.)

Rods: 0.375 to 0.5 by 1.5 to 3.0 microns, occurring singly and in chains. Non-motile. Spores central, 0.375 to 0.5 by 1.0 to 1.25 microns. Gram-positive.

Gelatin colonies: Grayish, with brown center.

Gelatin stab: Liquefaction infundibuliform, becoming stratiform.

Agar colonies: Small, grayish, slightly irregular, translucent, raised, viscid.

Agar slant: Scanty, slightly raised, grayish, finely wrinkled, translucent, viscid.

Broth: Slightly turbid, with granular pellicle.

Litmus milk: No coagulation. Peptonized. Alkaline.

Potato: Grayish, finely wrinkled, viscid.

Indol not formed.

Nitrates reduced to nitrites.

Acid in dextrose and sucrose.

Starch not hydrolyzed.

Blood serum is liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil. Isolated from dough.

70. **Bacillus adhaerens** Laubach. (Jour. of Bact., *1*, 1916, 503.)

Rods: 0.375 to 0.5 by 1.5 to 4.0 microns, occurring in long chains. Non-motile. Spores central, 0.625 to 0.75 by 0.875 to 1.0 micron. Gram-positive.

Gelatin colonies: Grayish, granular, slightly raised, center yellow-brown.

Gelatin stab: Slow, infundibuliform liquefaction.

Agar colonies: Grayish, spreading, filamentous, with elevated yellow-brown center.

Agar slant: Spreading, grayish, filamentous, moist, glistening, becoming dull.

Broth: Turbid, with grayish pellicle and sediment.

Litmus milk: No coagulation. Peptonization

Potato: Grayish-white, smooth, moist.

Indol not formed.

Nitrates not reduced.

Acid in dextrose and sucrose.

Starch not hydrolyzed.

Blood serum not liquefied.

Aerobic, facultative.

Optimum temperature 30°C.

Habitat: Soil.

71. **Bacillus viridi-glaucescens** Sack. (Cent. f. Bakt., II Abt., *65*, 1925, 113.)

Rods, bluish-green in color, 1.0 by 4.0 to 5.0 microns. Non-motile. Gram-positive. Spores oval, bluish-green.

Gelatin colonies.

Gelatin stab: Infundibuliform liquefaction.

Agar colonies: Circular, large, white, compact, slimy, becoming bluish-green.

Agar slant: Abundant, white, slimy, becoming bluish-green.

Broth: Turbid with sediment.

Litmus milk: Peptonized. Reduced.

Potato: Thick, white, slimy, becoming grayish-green.

Indol is formed.

Nitrates reduced to nitrites.

The organisms produce a mixture of a yellow and blue pigment.

Aerobic, facultative.

Optimum temperature 20° to 30°C.

Habitat: Soil.

72. **Bacillus fulminans** Schrire and Greenfield (Trans. Royal Soc. of So. Africa, *17*, 1930, 309).

Rods, 0.35 to 1.25 by 3.5 to 8.0 microns, occurring in chains. Spores oval, central with slight bulging sides of the rod. Non-motile. Gram-positive.

Gelatin stab: Crateriform liquefaction.

Agar colonies: Grayish-white, spreading, rhizoid, rough, with indented margin.

Agar slant: Grayish, coarsely granular, spreading, fimbriate.

Broth: Thick pellicle with grayish, powdery sediment.

Litmus milk: Peptonized, reduced.
Potato: Creamy-white, glistening, smooth.
Indol is formed.
Nitrates are reduced.
Blood serum is peptonized.
Starch is hydrolyzed.
Acid in dextrose, levulose, maltose, sucrose, salicin, dextrin and glycerol.
Aerobic, facultative.
Optimum temperature 33°C.
Habitat: Abscess of muscle of frog and guinea pigs, producing hemorrhagic edema.

73. **Bacillus aurantius** (Sack) Bergey et al. (*Cellulomonas aurantius* Sack, Cent. f. Bakt., II Abt., *62*, 1924, 78; Bergey et al., Manual, 3rd ed., 1930, 421.)
Rods: 0.5 by 1.0 micron. Spores. Non-motile. Gram-positive.
Gelatin colonies: Circular, orange-colored, entire.
Gelatin stab: Arborescent growth in stab. No liquefaction.
Agar colonies: Large, circular, light orange-colored, becoming darker. Fimbriate margin.
Agar slant: Orange-colored streak.
Broth: Shows distinct sediment.
Litmus milk: Unchanged.
Potato: Abundant, orange-colored streak.
Indol not formed.
Nitrates reduced to nitrites and ammonia.
H_2S formed.
Cellulose hydrolyzed.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Soil.

74. **Bacillus thermodiastaticus** Bergey et al. (Type 1, Bergey, Jour. of Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 310.)
Rods: 0.5 to 0.7 by 2.0 to 3.0 microns, with square ends, occurring in long chains. Motile with peritrichous flagella. Spores central, of lesser diameter than the rods. Gram-positive.
Gelatin stab: Liquefied.
Agar colonies: Spreading, grayish, with lobate to fimbriate margin.
Agar slant: Thin, limited, bluish-gray streak, entire margin.
Broth: Turbid.
Litmus milk: Acid coagulation. Litmus reduced.
Potato: Slight grayish growth.
Indol not formed.
Nitrates reduced to nitrites.
Starch is hydrolyzed.
Aerobic, facultative.

Optimum temperature 65°C. Shows growth at 75°C. No growth at 50°C.

Thermal death-point, 5 to 8 hours at 100°C.

Habitat: Isolated from milk and dust.

75. **Bacillus nondiastaticus** Bergey et al. (Type 2, Bergey, Jour. of Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 310.)

Rods: 0.4 to 0.6 by 2.0 to 3.0 microns, with rounded ends, occurring in chains. Spores central, of greater diameter than the rods. Motile with peritrichous flagella. Gram-positive.

Gelatin stab: Liquefaction by some strains.

Agar colonies: Pale, grayish, spreading widely over the surface.

Agar slant: Thin, grayish, veil-like growth covering the surface.

Broth: Turbid, with dense sediment.

Litmus milk: Slightly acid, becoming alkaline. No coagulation. Peptonized.

Potato: Shows no growth.

Indol not formed.

Nitrates show slight reduction to nitrites.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 65°C. Grows at 75°C. Shows slight growth at 37°C.

Thermal death-point, 5 hours at 100°C.

Habitat: Isolated from dust and from soil.

76. **Bacillus lobatus** Bergey et al. (Type 3, Bergey, Jour. of Bact., *4*, 1919, 304; Bergey et al., Manual, 1st. ed., 1923, 311.)

Rods: 0.4 to 0.6 by 2.0 to 3.0 microns, occurring singly. Motile with peritrichous flagella. Spores central, of greater diameter than the rods. Gram-positive.

Gelatin stab: Liquefied.

Agar colonies: Grayish, spreading, with lobate margin.

Broth: Turbid.

Litmus milk: Slightly acid, becoming alkaline.

Potato: No growth.

Indol not formed.

Nitrates show slight reduction to nitrites.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 60°C. Grows at 70°C., and slightly at 37°C.

Thermal death-point, 3 to 4 hours at 100°C.

Habitat: Isolated from soil and horse manure.

77. **Bacillus thermoamylolyticus** Coolhaas. (Cent. f. Bakt., II Abt., *75*, 1928, 351.)

Rods with rounded ends, 0.6 by 3.0 to 6.0 microns. Spores central, 0.6 by 1.5 microns. Motile. Gram-positive.

Starch agar colonies: Large, circular.
Dextrose agar colonies: Small, circular, transparent.
Dextrose agar slant: Abundant growth.
Broth: Very slight growth.
Litmus milk: Unchanged.
Potato: Slight growth.
Indol not formed.
Nitrates reduced to nitrites.
Proteolytic action slight.
Hydrolysis of starch is active.
Gas in dextrose, levulose, galactose, lactose, maltose, sucrose, dextrin, amylum and glycerol, consisting of equal parts of CO_2 and H_2. The acids formed are butyric, lactic, acetic and propionic.
Aerobic, facultative.
Optimum temperature 55°C.
Habitat: Soil.

78. **Bacillus thermoalimentophilus** Weinzirl. (Jour. of Medical Research, *39*, 1919, 402.)
Long rods: 0.6 by 3.0 microns, with rounded ends, occurring singly. Motile. Spores terminal, 0.8 by 1.0 micron. Gram-positive.
Gelatin stab. No growth at 20°C.
Agar colonies: Circular, smooth, raised, amorphous, entire.
Agar slant: Moderate, spreading, effused, glistening, smooth, translucent, butyrous.
Broth: Turbid, with ring formation.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates reduced to nitrites and ammonia.
No acid in carbohydrate media.
Starch is not hydrolyzed.
Aerobic, facultative.
Optimum temperature 55°C. Grows at 37°C., but not at 20°C.
Habitat: Isolated from canned blueberries.

79. **Bacillus thermocellulolyticus** Coolhaas. (Cent. f. Bakt., II Abt., *76*, 1928, 43.)
Thin rods: 0.3 by 3.4 to 4.0 microns. Spores terminal, 0.8 by 1.5 microns. Non-motile. Gram-positive.
Gelatin stab: No liquefaction.
Cellulose agar colonies: Circular, gray, granular, entire.
Sucrose agar colonies: Circular, transparent, undulate.
Broth: Slight turbidity.
Litmus milk: Unchanged.
Potato.
Indol not formed.

Nitrates not reduced.
Starch and cellulose hydrolyzed.
Other carbohydrates not attacked.
Aerobic, facultative.
Optimum temperature 50° to 55°C.
Habitat: Sewage.

80. **Bacillus cylindricus** Blau. (Cent. f. Bakt., II Abt., *15*, 1906, 119.)

Rods: 0.8 to 1.0 by 4.5 to 7.5 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores terminal, 0.9 by 2.5 microns. Cells store glycogen as reserve material. Gram-positive.

Gelatin stab: No liquefaction.
Agar colonies: Irregular, grayish-white, entire to lobed.
Agar slant: Thin, whitish to yellowish-white, spreading, lobed, homogeneous.
Broth: Turbid.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Starch is hydrolyzed.
Aerobic, facultative.
Optimum temperature 60° to 70°C.
Habitat: Soil.

81. **Bacillus stearothermophilus** Donk. (Jour. Bact., *5*, 1920, 373; Also Cameron and Esty, Jour. Infect. Dis., *39*, 1926, 89.)

Rods: 0.8 by 3.5 microns, occurring singly, in pairs and in short chains. Spores terminal. Motile with peritrichous flagella. Gram-negative.

Gelatin colonies.
Gelatin stab: No liquefaction.
Agar colonies: Gray, smooth, flat, entire.
Agar slant: Filiform, dirty-white, translucent, butyrous.
Broth: Turbid.
Litmus milk: Acid, coagulated and peptonized. Litmus reduced.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Starch hydrolyzed.
Acid formed in dextrose, galactose, mannose, lactose, maltose and sucrose.
Aerobic, facultative.
Optimum temperature 50° to 55°C.
Habitat: Causing "flat sour" in canned vegetables.

82. **Bacillus thermotranslucens** Bergey et al. (Type 5, var. b., Bergey, Jour. of Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 312.)

Rods: 0.3 to 0.4 by 1.0 to 1.5 microns, occurring singly. Motile with peritrichous flagella. Spores terminal, of larger diameter than the rods. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies: Thin, transparent, veil-like, spreading widely over the surface.

Agar slant: Thin, veil-like, spreading.

Broth: Turbid.

Litmus milk: Slightly acid. No coagulation.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Starch slightly hydrolyzed.

Aerobic, facultative.

Optimum temperature 60°C. No growth at 70°C. Slight growth at 37°C.

Thermal death-point 15 minutes at 100°C.

Habitat: Isolated from guinea pig feces, from dust and from cheese.

83. **Bacillus thermononliquefaciens** Bergey et al. (Type 4, Bergey, Jour. of Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 312.)

Rods: 0.6 to 0.8 by 2.0 to 4.0 microns, with rounded ends, occurring singly. Motile with peritrichous flagella. Spores terminal, of greater diameter than the rods. Gram-positive.

Gelatin stab: May or may not be liquefied.

Agar colonies: Thin, pale, spreading, curled.

Agar slant: Rather thick, grayish, fimbriate.

Broth: Turbid.

Litmus milk: Slightly acid. No coagulation.

Potato: No growth.

Indol not formed.

Nitrates reduced to nitrites.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 70°C. Grows well at 75°C.

Thermal death-point, 3 hours at 100°C.

Habitat: Isolated from milk, soil, horse manure and rabbit feces.

84. **Bacillus thermoliquefaciens** Bergey et al. (Type 5, var. a., Bergey, Jour. of Bact., *4*, 1919, 304; Bergey et al., Manual, 1st ed., 1923, 313.)

Rods: 0.2 to 0.4 by 2.0 to 3.0 microns, with rounded ends, occurring singly. Motile with peritrichous flagella. Spores terminal, of greater diameter than the rods. Gram-positive.

Gelatin stab: Liquefied.

Agar colonies: Moderately dense, lobate.

Agar slant: Rather dense, grayish, lobate to fimbriate margin.

Broth: Turbid.

Litmus milk: Acid with coagulation. Litmus reduced.

Potato: No growth.
Indol not formed.
Nitrates reduced to nitrites.
Starch not hydrolyzed.
Acid in dextrose, lactose and sucrose.
Acetyl-methyl-carbinol is formed in dextrose broth.
Optimum temperature 60°C. No growth at 70°C. Slight growth at 37°C.
Thermal death-point, one hour at 100°C.
Habitat: Isolated from oats and horse manure.

85. **Bacillus kaustophilus** Prickett. (Tech. Bul. No. 147, N. Y. Agr. Exp. Sta., 1928, 38.)

Rods with rounded ends, 0.7 by 2.0 to 4.5 microns, occurring singly and in short chains. Motile. Spores terminal, 0.4 to 0.5 by 0.8 micron. Gram-positive.

Gelatin stab: Liquefied.
Agar colonies: Circular, brown, smooth, convex, filamentous.
Agar slant: Abundant, brownish-gray, filiform, raised, glistening, translucent.
Broth: Turbid.
Litmus milk: Coagulated; slowly peptonized. Litmus reduced.
Potato: Spreading, slimy, glistening, brownish growth.
Indol not formed.
Nitrates reduced to nitrites and nitrogen.
Starch hydrolyzed.
H_2S not formed.
Ammonia formed from peptone.
Acid formed in glucose and salicin.
Aerobic, facultative.
Optimum temperature 60° to 65°C.
Habitat: Isolated from pasteurized milk.

86. **Bacillus thermoindifferens** Weinzirl. (Jour. of Medical Research, *39*, 1919, 402.)

Rods: 0.8 by 3.5 microns, with rounded ends, occurring singly and in chains. Motile. Spores terminal, 1.0 by 1.5 microns. Gram-positive.

Gelatin colonies: Circular, raised. Crateriform liquefaction.
Gelatin stab: Slow, infundibuliform liquefaction.
Agar colonies: Circular, smooth, raised, convex, amorphous, entire.
Agar slant: Moderate, spreading, flat, contoured, translucent, butyrous.
Broth: Turbid, with abundant sediment. No pellicle.
Litmus milk: Alkaline. Litmus reduced.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Starch is hydrolyzed.
Acid in dextrose.

Aerobic, facultative.
Optimum temperature 55°C. Good growth at 20° and at 37°C.
Habitat: Isolated from canned pumpkin.

87. **Bacillus aerothermophilus** Weinzirl. (Jour. of Medical Research, *39*, 1919, 403.)

Rods: 0.8 by 4.0 microns, occurring singly and in chains. Motile. Spores terminal, 1.0 by 1.5 microns. Gram-positive.
Gelatin stab: Liquefied at 55°C.
Agar colonies: Circular, smooth, convex, amorphous, entire.
Agar slant: Moderate, spreading, flat, glistening, contoured, translucent, butyrous.
Broth: Slightly turbid, with pellicle and abundant, flocculent sediment.
Litmus milk: Alkaline. Litmus reduced.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, sucrose and mannitol.
Starch is hydrolyzed.
Aerobic, facultative.
Optimum temperature 55°C. No growth at 20°C.
Habitat: Isolated from canned string beans.

88. **Bacillus michaelisii** Prickett. (*Bacillus thermophilus aquatilis liquefaciens* Michaelis, Arch. f. Hyg., *36*, 1899, 284; Tech. Bul. 147, N. Y. Agr. Exp. Sta., 1928, 45.)

Rods: 0.6 to 0.8 by 2.0 to 4.0 microns. Motile. Spores terminal, producing swelling of the rod. Gram-positive.
Gelatin stab: Slow liquefaction.
Agar colonies: Circular, raised, smooth, glistening.
Agar slant: Moderate, smooth, glistening.
Broth: May show slight turbidity after 6 days.
Litmus milk: Alkaline.
Potato: Yellowish, moist, glistening, becoming brownish.
Indol not formed.
Nitrates reduced.
Starch hydrolyzed.
H_2S not formed.
NH_3 formed from peptone.
Acid in dextrose and sucrose but not in lactose.
Aerobic, facultative.
Optimum temperature 50° to 60°C.
Habitat: Fodder, dust, dairy utensils.

89. **Bacillus robustus** Blau. (Cent. f. Bakt., II Abt., *15*, 1906, 126.)

Rods: 1.0 to 1.3 by 3.0 to 3.5 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores central, 0.9 to 1.0 by 2.0 microns. Cells store glycogen as reserve material. Gram-positive.

Agar colonies: Thin, yellowish-white, spreading, translucent, serrate to lobed margin.
Agar slant: Thin, spreading, yellowish-white.
Broth: Turbid.
Litmus milk.
Potato: Slight yellowish growth.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 55° to 60°C. Will grow at 65°C.
Habitat: Soil.

90. **Bacillus losanitchi** Bergey et al. (*Bacillus thermophilus losanitchi* Georgevitch, Cent. f. Bakt., II Abt., *27*, 1910, 150; Bergey et al., Manual, 1st. ed., 1923, 313.)

Rods: 1.0 by 3.0 microns, occurring singly, in pairs, and in chains. Motile with peritrichous flagella. Spores central, 0.5 by 1.0 microns. Gram-positive.
Agar colonies: Circular, dark yellow, entire.
Agar slant: Dark yellow, spreading, covering the entire surface
Broth: Turbid, with thick, dirty-white pellicle.
Litmus milk.
Potato: Whitish, glistening, granular, becoming dry and dirty-white.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 72° to 73°C. Grows between 45° and 78°C.
Habitat: Thermal spring at Vranje. The temperature of the water is 83°C.

91. **Bacillus viridulum** (Migula) *comb. nov.* (*Bacillus thermophilus II* Rabinowitsch, Zeitschr. f. Hyg., *20*, 1895, 154; *Bacterium viridulum* Migula, System der Bakterien, 1900, 343; *Bacterium thermophilum II* Chester, Manual, 1900, 186; *Bacillus thermophilus* Bergey et al., Manual, 1st. ed., 1923, 315; Not *Bacillus thermophilus* Miquel, Ann. de. Microg., *1*, 1888, 6; Not *Bacillus thermophilus* Chester, Manual, 1900, 265.)

Rods, slightly bent, occuring singly and in pairs. Non-motile. Spores central. Gram-positive.
Agar colonies: Greenish, granular, spreading, irregular.
Agar slant.
Broth: Becomes alkaline.
Litmus milk.
Potato: Grayish-yellow, with undulate margin.
Indol not formed.
Nitrates not reduced.

Starch is hydrolyzed.
Aerobic, facultative.
Optimum temperature 62°C.
Habitat: Soil.

92. **Bacillus calidus** Blau. (Cent. f. Bakt., II Abt., *15*, 1906, 134.)

Rods: 0.8 to 1.0 by 4.5 microns, occurring singly, in pairs and short chains. Motile with peritrichous flagella. Spores terminal, 0.8 by 1.8 to 1.9 microns. Cells store glycogen and volutin as reserve materials. Gram-positive.

Gelatin stab: No liquefaction.
Agar colonies: Circular, grayish-white, lobulate.
Agar slant: Yellowish-white, spreading, lobulate.
Broth: Turbid.
Litmus milk: Alkaline; coagulated; peptonized.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Starch not hydrolyzed.
Aerobic, facultative.
Optimum temperature 60° to 65°C.
Habitat: Soil.

93. **Bacillus tostus** Blau. (Cent. f. Bakt., II Abt., *15*, 1906, 130.)

Rods: 1.4 to 1.5 by 4.5 to 5.0 microns, occurring singly, in pairs and short chains. Motile with peritrichous flagella. Spores terminal, 0.4 by 2.0 microns. Cells store glycogen as reserve material. Gram-positive.

Agar colonies: Small, white to yellowish-white, circular, raised.
Agar slant: Thin, grayish-white, spreading, smooth, glistening.
Broth: Turbid.
Litmus milk.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Starch is hydrolyzed.
Aerobic, facultative.
Optimum temperature 60° to 70°C.
Habitat: Soil.

94. **Bacillus calidolactis** Hussong and Hammer. (Jour. of Bact., *15*, 1928, 186.)

Rods: 0.7 to 1.4 by 2.6 to 5.0 microns, occurring singly and occasionally in pairs and short chains. Spores terminal causing slight swelling of the rod. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.
Dextrose agar colonies: Thin, white, opaque, filamentous.
Dextrose agar slant: Abundant, echinulate, dull, white growth.
Dextrose broth: Turbid.

Litmus milk: Acid, coagulated. Litmus reduced.
Potato: No growth.
Indol not formed
Nitrates are reduced by some strains.
Acid formed in dextrose, levulose, galactose, maltose, lactose, raffinose and dextrin. Some strains also form acid in sucrose, salicin and glycerol. No action on inulin, mannitol, dulcitol, adonitol, sorbitol or inositol.
Aerobic, facultative.
Optimum temperature 55° to 65°C. No growth at 37°C.
Habitat: Isolated from heated milk.

95. **Bacillus pepo** Shaw. (Jour. of Infect. Dis., *43*, 1928, 473.)
Rods: From 3 to 20 microns in length. Spores terminal. Non-motile. Gram-positive.
Gelatin stab: Slow liquefaction.
Agar colonies: Circular, gray, concentric rings with radiations.
Agar slant.
Broth: Turbid with viscid sediment.
Litmus milk: Slimy. Litmus reduced. Slowly peptonized. No coagulation.
Potato: No growth.
Indol not formed.
Nitrates reduced with gas formation.
H_2S formed.
Starch slowly hydrolyzed.
Acid formed in dextrose, levulose, galactose, maltose, raffinose, salicin and mannitol.
Aerobic, facultative.
Optimum temperature 55° to 62.5°C.
Habitat: Isolated from canned foods.

Note: Beaver, (Dissertation, Ohio State University, Columbus, Ohio, 1932) has described and named 23 new species of thermophilic spore forming rods. Inasmuch as he has regarded each of the 42 thermophilic cultures (39 spore forming rods) isolated from a variety of common materials (canned goods, dairy products, soil, water, dust, sewage, etc.) as belonging to separate species it seems scarcely worth while to describe each one of the 23 new species. Species distinctions are based on trivial differences such as slight differences in growth on potato, aerobic growth vs. slightly facultative anaerobic growth, nitrate reduction in 5 days vs. reduction in 18 hours, etc. Nine of the 23 new species of *Bacillus* produced central spores, while 14 produced sub-terminal spores. All are reported as giving optimum growth at 55° to 58°C. Only 6 however, grew at 37°C. All of the new species are motile. The names given the proposed new species are: *Bacillus thermobutyrosus, Bacillus thermourinalis, Bacillus thermograni, Bacillus thermoannulatus, Bacillus thermoaquatilis, Bacillus thermolongus, Bacillus thermonubilosus, Bacillus thermocompactus, Bacillus thermoviscidus, Bacillus*

thermofiliformis, Bacillus thermopellitus, Bacillus thermoeffervescens, Bacillus thermosuavis, Bacillus thermoacetigenitus, Bacillus thermolubricans, Bacillus thermononodorus, Bacillus thermoactivus, Bacillus thermotenax, Bacillus thermodactylogenitus, Bacillus thermoodoratus, Bacillus thermofaecalis, Bacillus thermoarborescens, Bacillus thermoabundans.

Genus II. Clostridium *Prazmowski, 1880.*

Anaerobes or microaerophiles, often parasitic. Rods frequently enlarged at sporulation, producing clostridium or plectridium forms.

The type species is *Clostridium butyricum* Prazmowski.

Key to the species of genus Clostridium.

A. Spores central.
1. Rods not swollen at sporulation.
a. Motile.
b. Coagulated albumin not liquefied.
c. Brain medium not blackened.
d. Gelatin not liquefied.
1. *Clostridium butyricum.*
dd. Gelatin liquefied.
e. Acid and gas in dextrose.
2. *Clostridium mucosum.*
ee. Acid but no gas in dextrose.
3. *Clostridium pruchii.*
bb. Coagulated albumin liquefied.
c. Brain medium blackened.
d. Gelatin liquefied.
e. Acid and gas in dextrose.
f. Glycerol not fermented.
4. *Clostridium centrosporogenes.*
aa. Non-motile.
b. Coagulated albumin not liquefied.
c. Brain medium not blackened.
d. Gelatin liquefied.
e. Acid and gas in simple sugars.
f. Glycerol fermented.
g. Inulin fermented.
5. *Clostridium welchii.*
gg. Inulin not fermented.
5A. *Clostridium welchii* Type II.
ff. Glycerol not fermented.
g. Inulin fermented.
5B. *Clostridium welchii* Type III.
gg. Inulin not fermented.

5C. *Clostridium welchii* Type IV.

ee. Lactose not fermented.

6. *Clostridium bifermentans.*

dd. Gelatin not liquefied.

7. *Clostridium egens.*

2. Rods swollen at sporulation.
 a. Motile.
 b. Coagulated albumin not liquefied.
 c. Brain medium not blackened.
 d. Gelatin not liquefied.
 e. Glycerol fermented.

8. *Clostridium multifermentans.*

ee. Glycerol not fermented.

9. *Clostridium fallax.*

dd. Gelatin liquefied.
 e. Lactose fermented.
 f. Sucrose fermented.
 g. Salicin fermented.

10. *Clostridium oedematis-maligni.*

gg. Salicin not fermented.

11. *Clostridium chauvei.*

ee. Lactose not fermented.
 f. Glycerol fermented.

12. *Clostridium oedematiens.*

ff. Glycerol not fermented.

13. *Clostridium novyi.*

bb. Coagulated albumin liquefied.
 c. Brain medium blackened.
 d. Gelatin liquefied.
 e. Not pathogenic.
 f. No pigment formed.
 g. Lactose fermented.

14. *Clostridium aerofoetidum.*

gg. Lactose not fermented.

15. *Clostridium parasporogenes.*

ff. Yellow pigment formed.

16. *Clostridium baccarinii.*

ee. Pathogenic.
 f. Lactose not fermented.
 g. Filtrate non-toxic on feeding.

17. *Clostridium histolyticum.*

h. Not toxic on injection.

18. *Clostridium sporogenes.*

B. Spores terminal.
 1. Spores spherical, or nearly so.
 a. Motile.
 b. Coagulated albumin liquefied.

c. Brain medium blackened.
d. Gelatin liquefied.
e. Dextrose not fermented.
f. Toxic on injection.
19. *Clostridium tetani.*
ff. Not toxic.
20. *Clostridium putrificum.*
bb. Coagulated albumin not liquefied.
c. Brain medium not blackened.
d. Gelatin slowly liquefied.
e. Lactose and salicin not fermented.
21. *Clostridium tetanomorphum.*
dd. Gelatin not liquefied.
e. Lactose fermented.
f. Salicin fermented.
22. *Clostridium sphenoides.*
aa. Non-motile.
b. Coagulated albumin not liquefied.
c. Action on brain medium unknown.
d. Gelatin not liquefied.
e. Lactose fermented.
ff. Salicin not fermented.
g. Milk acid; coagulated.
23. *Clostridium filiformie.*
gg. Milk alkaline.
24. *Clostridium alcaligines.*
2. Spores oval or elongated.
a. Motile.
b. Coagulated albumin liquefied.
c. Filtrate toxic for guinea pigs on feeding.
25. *Clostridium botulinum.*
c. Filtrate non toxic on feeding.
26. *Clostridium tyrosinogenes.*
bb. Coagulated albumin not liquefied.
c. Brain medium not blackened.
d. Gelatin not liquefied.
e. Acid and gas in carbohydrate media.
f. Mannitol fermented.
27. *Clostridium tertium.*
ff. Mannitol not fermented.
28. *Clostridium fissum.*
29. *Clostridium flabelliferum.*
30. *Clostridium caloritolerans.*
ee. Carbohydrate not fermented.
31. *Clostridium cochlearum.*
cc. Action on brain medium unknown.
d. Gelatin liquefied.

e. Indol formed.
f. Acid in dextrose, lactose and sucrose.
32. *Clostridium regularis.*
f. Acid and gas in dextrose and lactose.
33. *Clostridium saccharolyticum.*
ee. Indol not formed.
f. Acid in dextrose.
34. *Clostridium filamentosum.*
35. *Clostridium zoogleicum.*
ff. Acid and gas in dextrose.
g. Milk coagulated.
36. *Clostridium coagulans.*
gg. Milk not coagulated; peptonized.
37. *Clostridium ovalaris.*
fff. No action on sugars.
g. No action on cellulose.
38. *Clostridium nigrificans.*
gg. Cellulose digested.
39. *Clostridium werneri.*
ggg. Starch and cellulose digested.
40. *Clostridium felsinae.*
ccc. Brain medium blackened.
d. Gelatin liquefied.
e. Acid and gas in carbohydrate media.
f. Mannitol not fermented.
41. *Clostridium oedematoides.*

aa. Non-motile.
b. Coagulated albumen softened.
c. Gelatin liquefied.
42. *Clostridium spermoides.*
bbb. Coagulated albumen not softened.
c. Gelatin not liquefied.
d. Nitrates reduced.
e. Acid but no gas in sucrose.
43. *Clostridium thermochainum.*
44. *Clostridium thermoacidophilum.*
ee. Gas but no acid in sucrose.
45. *Clostridium thermoputrificum.*
eee. No action on sucrose.
f. Starch is hydrolyzed.
46. *Clostridium thermoaerogenes.*
dd. Action on nitrates not given.
e. Starch not hydrolyzed.
47. *Clostridium lucileae.*
48. *Clostridium dissolvens.*

cc. Gelatin liquefied.
d. Nitrates not reduced.
e. Acid and gas in carbohydrate media.
49. *Clostridium putrefaciens.*

1. **Clostridium butyricum** Prazmowski. (*Amylobacter,* Prazmowski, Botan. Zeitung, *37,* 1879, 409; Prazmowski, Untersuchungen über die Entwickelungsgeschichte und Fermentwirkung einiger Bakterienarten, Inaug. Diss., Leipzig, 1880, 23; Vibrion butyrique Pasteur, Comp. rend., *52,* 1861, 344; *Bacillus amylobacter* v. Tieghem, Bull. de la soc. botan. de France, *24,* 1877, 128; *Bacterium navicula* Reinke u. Berthold, Untersuch. a. d. botan. Laborat. d. Univ. Göttingen, 1879; *Bacillus butylicus* Fitz, Ber. d. Deutsch. Chem. Ges., *17,* 1884, 1188; *Butylbacillus e* Buchner, Hoppe-Seyler, Zeitschr. f. physiol. Chemie, *9,* 1885, 380; *Bacillus amylobacter I,* Gruber, and *Bacillus amylobacter II,* Gruber, Cent. f. Bakt., *1,* 1887, 367; *Bacillus amylocyme* Perdrix, Ann. d. l'Institut Pasteur, *5,* 1891, 287; *Bacillus butyricus* Botkin, Zeit. f. Hyg., *11,* 1892, 421; *Granulobacter saccharobutyricum* Beijerinck, and *Granulobacter lactobutyricum* Beijerinck, Verhandl. d. K. Akad. v. Wetenschappen, Tweede Sectie, Deel I, Amsterdam, 1893; *Bacillus orthobutylicus* Grimbert, Ann. de l'Institut Pasteur, *7,* 1893, 353; *Amylobacter butylicus* Duclaux, Ann. de l'Institut Pasteur, *9,* 1895, 265; *Granulobacter butylicum* Beijerinck, Arch. Neerland, *29,* 1896, I; *Bacillus saccharobutyricus* v. Klecki, Cent. f. Bakt., II Abt. *2,* 1896, 169; Motile Buttersaurebacillus Grassberger u. Schattenfroh, Arch. f. Hyg., *12,* 1902, 219; Clostridium der Hanfröste Behrens, Cent. f. Bakt., II Abt., *8,* 1902, 114; *Clostridium pastorianum* Winogradsky, Cent. f. Bakt., II Abt., *9,* 1902, 43; *Plectridium plectinovorum* Stormer, Cent. f. Bakt., II Abt., *13,* 1904, 171; *Clostridium giganteum* Kentner, Wissensch. Meeresuntersuch., N. F., *8,* 1904; *Clostridium americanum* Pringsheim, Cent. f. Bakt., II Abt., *16,* 1906, 795; *Granulobacter pectinovorum* Beijerinck u. van Delden, and *Granulobacter urocephalum* Beijerinck u. van Delden, Arch. Neerland, Ser. II, *9,* 1906, 8; Alcohol bildendes Clostridium of Schardinger, Cent. f. Bakt., II Abt., *18,* 1907, 748, *Bacillus amylobacter* Bredemann, Cent. f. Bakt., II Abt., *23,* 1909, 385.)

Rods: 0.75 to 1.0 by 3.0 to 10.0 microns, occurring singly, in pairs and long chains. May produce slender forms 0.5 micron in width. Actively motile in young cultures, possessing peritrichous flagella. Spores oval, central, 1.0 by 2.0 to 2.5 microns; not swollen at sporulation. Cells store glycogen. Gram-positive.

Gelatin stab: No liquefaction.

Serum agar colonies (anaerobic): Small, flat, irregular, grayish, semi-transparent.

Plain and dextrose agar slant (anaerobic): Grayish, flat, moist, spreading, with irregular, lacerate margin. No surface growth aerobically.

Colonies in agar shake cultures, compact, with dense central portion and floccose, hazy periphery, 2 to 3 mm. in diameter.

Anaerobic agar stab: Granular, filiform growth.

Dextrose broth: Turbid.

Litmus milk: Acid, coagulation, with abundant gas formation. Early reduction of litmus.

Potato (with chalk): Shows thin, spreading, barely visible layer, forming later yellowish, raised points. The medium becomes soft and friable, with gas bubbles.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened.

Indol not formed.

Nitrates reduced to nitrites and ammonia.

Acid, gas and alcohols formed in dextrose, maltose, lactose, sucrose and starch, the amounts formed depending on the temperature, the quantity of fermentable carbohydrate, and the nitrogenous food materials available. The acids formed are principally butyric, with smaller quantities of propionic, acetic and formic. The gas formed consists of CO_2 and H_2. The alcohol formed consists of butyl, propyl, ethyl and traces of amyl, depending on the composition of the substances fermented. Usually about two parts alcohol are formed to one part acetone.

Fix atmospheric nitrogen.

Not pathogenic.

Anaerobic.

Optimum temperature 30°C. to 40°C.

Habitat: Soil.

2. **Clostridium mucosum** (Klein) *comb. nov.* (*Bacillus mucosus* Klein, Cent. f. Bakt., I Abt., 1901, *29*, 991; Not *Bacillus mucosus* Zimmermann, Die Bakterien unser Trink- und Nutzwässer, Chemnitzer, II, 1894, 8; Not *Bacterium mucosum* Migula, System der Bakterien, 1900, 315; *Bacillus kleinii* Buchanan and Hammer, Research Bul. 22, Iowa Agr. Exp. Sta., 276; *Clostridium kleinii* Bergey et al., Manual, 1st ed., 1923, 321.)

Rods: 1.3 by 2.0 to 5.0 microns, occurring singly and in chains. Motile. Spores central. Rods not swollen at sporulation. Gram-positive.

Does not grow in media without carbohydrate.

Dextrose gelatin colonies: Small, gray.

Dextrose gelatin stab: Villous growth in stab. Slow liquefaction.

Dextrose agar slant: Thin, veil-like layer.

Dextrose broth: Turbid. Gas bubbles.

Litmus milk: Acid, slimy. Gas formed. Odor of butyric acid.

Potato: No growth.

Blood serum not liquefied.

No indol formed.

Nitrates not reduced.

Non-pathogenic.

Anaerobic.

Optimum temperature 37°C.

Habitat: Slimy milk.

3. **Clostridium pruchii** (Buchanan and Hammer) Bergey et al. (*Bacillus lactis pruchii* Conn, Esten and Stocking, Ann. Rept. Storrs Agr. Exp. Sta., 1906; *Bacillus pruchii* Buchanan and Hammer, Research Bul. No. 22, Iowa Agr. Exp. Sta., 276; Bergey et al., Manuel, 1st ed., 1923, 322.)

Rods, of variable size, with club-shaped ends. Motile, possessing peritrichous flagella. Spores central. Rods not swollen at sporulation. Gram-positive.

Gelatin colonies: Not characteristic. Liquefy rapidly.

Gelatin stab: Rapid, stratiform liquefaction.

Agar colonies: Round, flat, white, smooth, opaque.

Agar slant: Luxuriant, white, viscid.

Broth: Turbid, with flocculent pellicle and gray viscid sediment.

Litmus milk: Acid, coagulated, becoming yellow.

Potato: Thin, brownish, spreading.

Indol not formed.

Nitrates not reduced.

Acid in dextrose media.

Blood serum not liquefied.

Non-pathogenic.

Anaerobic.

Optimum temperature 30°C.

Habitat: Slimy milk.

4. **Clostridium centrosporogenes** (Hall) Bergey et al. (*Bacillus centrosporogenes* Hall, Jour. Infect. Dis., *30*, 1922, 464; Bergey et al., Manual, 1st ed., 1923, 322.)

Rods, large, occurring singly, in pairs and in chains, with centrally located spores. Rods not swollen at sporulation. Motile. Gram-positive.

Gelatin stab: Liquefied and blackened.

Blood agar colonies: At first small, hemolytic, transparent, becoming opaque, yellowish, spreading.

Broth: Turbid.

Litmus milk: Slowly coagulated peptonized. Slight gas formation.

Potato.

Indol not formed.

Nitrates not reduced

Acid and gas in dextrose. Glycerol not fermented.

Markedly proteolytic; liquefies coagulated egg-white.

Produces tyrosin.

Brain medium blackened.

Non-pathogenic.

Anaerobic.

Optimum temperature 37°C.

Habitat: Soil. Isolated from spoiled canned spinach.

5. **Clostridium welchii** (Migula) Holland. (*Bacillus aerogenes capsulatus* Welch and Nuttall, Johns Hopkins Hosp. Bull., *3*, 1892, 81; *Bacillus phleg-*

monis emphysematosae Fraenkel, Über Gasphlegmon, 1893; *Bacillus enteriditis sporogenes* Klein, Cent. f. Bakt., I Abt., *18*, 1895, 737; *Bacillus perfringens* Veillon and Zuber, Arch. med. exp., *10*, 1898, 517; *Bacterium welchii* Migula, System der Bakterien, 1900, 392; *Bacillus saccharobutyricus immobilus* Schattenfroh and Grassberger, Arch. f. Hyg., *37*, 1900, 54; *Bacillus welchii* Lehmann and Neumann, Bakt. Diag., 4 Auf., *2*, 1907, 457; Holland, Jour. Bact., *5*, 1920, 215.)

Rods, short, thick, 1.0 to 1.5 by 4.0 to 8.0 microns, occurring singly and in pairs, less frequently in short chains. Non-motile. Spores oval, central. Encapsulated. Gram-positive.

Gelatin stab: Liquefied and blackened.

Agar colonies: Circular, moist, slightly raised, opaque center, entire.

Broth: Turbid; peptolytic.

Litmus milk: Acid; coagulated, with profuse gas formation.

Potato: Thin, grayish-white streak. Gas in subtended liquid.

Indol not formed.

Nitrates not reduced.

Acid and gas in dextrose, levulose, galactose, mannose, maltose, lactose, sucrose, xylose, trehalose, raffinose, inulin, amylum, glycogen, glycerol and inositol.

Blood serum not liquefied.

Brain medium not blackened.

Egg-meat medium: Profuse gas production in eight hours. The meat is reddened and the liquid becomes turbid. No digestion.

Pathogenic for guinea pigs, pigeons and mice. Produces an exotoxin for which an antitoxin can be prepared.

Anaerobic.

Optimum temperature 35° to 37°C. Can grow at 50°C.

Habitat: The cause of gas gangrene.

5A. *Clostridium welchii* Type II. Differs from Type I in its inability to ferment inulin.

5B. *Clostridium welchii* Type III. Differs from Type I in its inabilitv to ferment glycerol.

5C. *Clostridium welchii* Type IV. Differs from Type I in its inability to ferment either glycerol or inulin.

6. **Clostridium bifermentans** Bergey et al. (*Bacillus bifermentans sporogenes* Tissier and Martelly, Ann. de l'Institut Pasteur, *16*, 1902, 865; Bergey et al., Manual, 1st ed., 1923, 323.)

Rods: 0.8 to 1.0 by 5.0 to 6.0 microns, occurring singly and in short chains. Non-motile. Spores, oval, central. Rods not swollen at sporulation. Gram-positive.

Gelatin stab: Liquefied. Gas bubbles.

Agar colonies: Circular, crenated to amoeboid.

Agar slant: Gray, spreading.

Broth: Turbid. Gas. Thick mucous sediment.

Litmus milk: Slowly coagulated. Slow peptonization, with slight gas formation.

Potato.

Indol not formed.

Nitrates not reduced.

Acid and gas in dextrose, levulose, mannose, maltose and glycerol. Acid in sorbitol. Lactose, sucrose, salicin, and inulin not fermented.

Brain medium not blackened.

Blood serum liquefied in three days. Liquid darkened.

Egg-meat medium: Some gas production in eight hours. The meat is slightly reddened and the liquid becomes turbid. After two days, digestion is apparent and the meat is darkened.

Non-pathogenic.

Anaerobic.

Optimum temperature 30° to 35°C. Can grow at 50°C.

Habitat: Soil.

7. **Clostridium egens** (Stoddard) Bergey et al. (*Bacillus egens* Stoddard, Jour. Exp. Med., *29*, 1919, 187; Bergey et al., Manual, 1st ed., 1923, 324.)

Rods, of same size and shape as Clostridium welchii. In bouillon the organisms show a well-defined capsule. Non-motile. Gram-positive, becoming Gram-negative. Spores central.

Gelatin: No liquefaction.

Dextrose agar colonies: Flat, circular, entire, bluish-gray.

Blood agar colonies: Definite hemolytic zone.

Broth: Diffuse clouding with fine sediment.

Litmus milk: Slow development. Acid, with coagulation; no peptonization. Little or no gas is formed.

Potato.

No indol is formed.

Acid and gas in dextrose, maltose, sucrose, lactose, galactose and raffinose.

Blood serum not liquefied.

Brain medium blackened.

Pathogenic for rabbits and guinea pigs.

Anaerobic.

Optimum temperature 35° to 37°C.

Habitat: Isolated from case of gas gangrene.

8. **Clostridium multifermentans** Bergey et al. (*Bacillus multifermentans tenalbus* Stoddard, The Lancet, London, 1919; Bergey et al., Manual, 1st ed., 1923, 324.)

Rods, large, with rounded ends, occurring singly and in short chains. Motile with peritrichous flagella. Spores central. Gram-positive.

Gelatin stab: Not liquefied.

Dextrose agar colonies: Circular, opaque, with irregular margin.

Dextrose agar slant: White, opaque, raised streak.
Blood agar colonies: Zone of hemolysis in 24 hours.
Broth: Turbid.
Litmus milk: Acid; coagulated; digested.
Potato.
Indol not formed.
Acid and gas in dextrose, levulose, galactose, maltose, lactose, sucrose, raffinose, amylum, salicin, inulin and glycerol.
Coagulated albumin not liquefied.
Blood serum not liquefied.
Brain medium not blackened.
Not pathogenic.
Anaerobic.
Optimum temperature 30° to 35°C.
Habitat: Soil.

9. **Clostridium fallax** (Weinberg and Sequin) Bergey et al. (Compt. rend. Soc. de Biol., Paris, *78*, 1915, 666; Bergey et al., Manual, 1st ed., 1923, 325.)
Rods: 0.6 to 0.8 by 3.0 to 6.0 microns, occurring singly. Motile with peritrichous flagella. Spores central. Gram-positive.
Gelatin stab: Not liquefied.
Agar colonies: Circular, flat, with transparent, crenated margin.
Agar slant: Grayish film.
Broth: Turbid.
Litmus milk: Acid; coagulated. Gas is formed.
Potato.
Acid in dextrose, galactose, levulose, maltose, lactose, sucrose, inulin and amylum. No acid in glycerol or mannitol.
Blood serum not liquefied.
Brain medium not blackened.
Pathogenic for guinea pigs. Forms an exotoxin.
Anaerobic.
Optimum temperature 37°C.
Habitat: Soil.

10. **Clostridium oedematis-maligni** (Flügge) Bergey et al. (Vibrion septique, Pasteur, Bull. Acad. de Med., Paris, 1877, II Ser., 781, Milzbrandbacillen, Koch, Mitt. Kais. Ges. A., *1*, 1881, 49; *Bacillus oedematis maligni* Flügge, Die Microorganismen, 1886, 193; Bergey et al., Manual, 1st ed., 1923, 325.)
Rods: 0.6 to 1.0 by 3.0 to 8.0 microns, with rounded ends, occurring principally in long chains. Motile with peritrichous flagella. Spores oval, central. Gram-positive.
Gelatin stab: Liquefied. Gas bubbles.
Agar colonies: Delicate, spreading, semi-transparent, becoming grayish, crenated.
Agar slant: Grayish, spreading.

Broth: Turbid; clearing. Disagreeable odor.

Litmus milk: Acid; coagulated. Gas is formed.

Potato.

Acid and gas in dextrose, levulose, galactose, mannose, maltose, lactose, dextrin, salicin, melezitose and trehalose. No action on sucrose or inulin.

Blood serum not liquefied.

Brain medium not blackened.

Egg-meat medium: Profuse gas production in eight hours. The meat becomes pinkish and the liquid more or less turbid. No digestion.

Pathogenic for guinea pigs, rabbits, mice and pigeons. Forms an exotoxin.

Anaerobic.

Optimum temperature 37°C.

Habitat: The cause of malignant edema.

11. **Clostridium chauvei** (Arloing et al.) Holland. (*Bacillus chauvei* Arloing, Cornevin and Thomas, Le charbon symptomatique du boeuf, Paris, 2nd ed., 1887, 405; Holland, Jour. Bact., *5*, 1920, 215.

Rods: 1.0 by 3.0 to 8.0 microns, occurring singly and in short chains. Usually show a dark chromatic point near each extremity. Motile with peritrichous flagella. Spores oval, central. Gram-positive.

Gelatin stab: Liquefied. Gas bubbles.

Agar colonies: Small, grayish, semi-opaque, filamentous.

Agar slant: Grayish, spreading.

Broth: Turbid, slightly peptolytic.

Litmus milk: Acid; coagulated. Gas may be formed.

Potato.

Trace of indol is formed.

Acid and gas in dextrose, levulose, galactose, maltose, lactose, sucrose and dextrin. Acid in glycerol. Salicin not fermented.

Blood serum not liquefied.

Brain medium not blackened.

Egg-meat medium: Small gas bubbles in eight hours. Meat becomes pinkish and the liquid slightly turbid. No digestion.

Pathogenic for guinea pigs and mice. Forms an exotoxin.

Anaerobic.

Optimum temperature 37°C. Can grow at 50°C.

Habitat: The cause of "black leg" or "black quarter" or symptomatic anthrax in cattle.

12. **Clostridium oedematiens** (Weinberg and Seguin) Bergey et al. (*Bacillus oedematiens* Weinberg and Seguin, Compt. rend. Soc. de Biol., Paris, *81*, 1918, 184; Bergey et al., Manual, 1st ed., 1923, 236.)

Synonyms: *Bacillus neigeux* Costa and Troisier, Compt. rend. Soc. de Biol., 78, 1915, 352; Gas-oedema bacillus of Aschoff, Veröffentl. a. d. Geb. d. Mil. Sanitätswesens, *68*, 1918, 1.

Rods: 0.8 to 1.0 by 4.5 microns, with rounded ends, occurring singly and

in long chains. Motility slight. Spores oval, central, slightly flattened at the ends. Gram-positive.

Gelatin stab: Liquefied.

Agar colonies: Flat, transparent, spreading with sinuous margin.

Agar slant: Grayish, spreading.

Broth: Shows flocculent sediment.

Litmus milk: Acid, with slow coagulation.

Potato.

Acid and gas in dextrose, levulose, galactose, maltose and soluble starch.

Blood serum not liquefied.

Brain medium not blackened.

Egg-meat medium: Much gas in 24 hours. The meat turns slightly pinkish and the liquid becomes slightly turbid. No digestion.

Pathogenic for guinea pigs, mice and pigeons. Forms an exotoxin.

Anaerobic.

Optimum temperature 35° to 37°C. Can grow at 50°C.

Habitat: Soil.

13. **Clostridium novyi** Bergey et al. (*Bacillus oedematis II* Novy, Zeitschr. f. Hyg., *17*, 1894, 209; Bergey et al., Manual, 1st ed., 1923, 236.)

Rods: 0.8 to 0.9 by 2.5 to 5.0 microns, occurring singly. Motile with peritrichous flagella. Spores central. Gram-positive.

Gelatin stab: Liquefied and blackened.

Agar colonies: Small white, with darker center, filamentous.

Agar slant: Grayish, spreading.

Broth: Turbid, with flocculent sediment.

Litmus milk: Acid. Litmus reduced.

Potato.

Acid and gas in dextrose, levulose, xylose, maltose, starch and glycerol. Lactose not fermented.

Coagulated albumin not liquefied.

Blood serum not liquefied.

Brain medium not blackened.

Pathogenic for guinea pigs, rabbits, mice, cats, rats and pigeons.

Anaerobic.

Optimum temperature 35° to 38°C.

Habitat: Found in a solution of nuclein from milk.

14. **Clostridium aerofoetidum** (Weinberg and Seguin) Bergey et al. (*Bacillus aerofoetidus*, Weinberg and Seguin, Compt. rend. soc. de Biol., *79*, 1916, 116; Bergey et al., Manual, 1st ed., 1923, 327.

Rods: 0.4 to 0.6 by 3.0 to 5.0 microns, occurring singly and in short chains. Motile with peritrichous flagella. Spores oval, central. Gram-positive.

Gelatin stab: Liquefied.

Agar colonies: Circular, transparent, with faintly bluish tint, fimbriate.

Broth: Turbid; with sediment.

Litmus milk: Acid; coagulated; followed by peptonization. Shows gas formation.

Potato.

Acid and gas in dextrose, levulose, galactose, mannose, maltose, lactose, xylose, amygdalin, salicin, esculin and glycogen. Does not attack sucrose, inulin, glycerol or mannitol.

Blood serum is liquefied.

Brain medium blackened.

Slightly pathogenic for guinea pigs.

Anaerobic.

Optimum temperature 30° to 35°C.

Habitat: Soil.

15. **Clostridium parasporogenes** (McIntosh) Bergey et al. (*Bacillus parasporogenes* McIntosh, Med. Research Com., Special Report Series, No. 12, 1917, 37; Bergey et al., Manual, 1st ed., 1923, 327.)

Rods, with rounded ends, occurring singly, less frequently in short chains. Motile with peritrichous flagella. Spores oval, central. Gram-positive.

Gelatin stab: Liquefied.

Agar colonies: Circular, opaque, filamentous.

Agar slant.

Broth.

Litmus milk: Coagulated; litmus reduced. Slow peptonization.

Potato.

Acid and gas in dextrose, levulose and maltose.

Blood serum is liquefied.

Brain medium blackened.

Pathogenic for young guinea pigs.

Anaerobic.

Optimum temperature 30° to 35°C.

Habitat: Soil.

16. **Clostridium baccarinii** (Macchiati) Bergey et al. (*Bacillus baccarinii* Macchiati, Cent. f. Bakt., II Abt., *4*, 1898, 332; Bergey et al., Manual, 1st ed., 1923, 328.)

Rods: 0.65 to 0.8 by 2.0 to 2.5 microns, occurring singly and in chains. The cells are surrounded by a slimy material which causes them to form zoogleal masses. Motile with peritrichous flagella. Spores central. Gram-positive.

Gelatin stab: Slow liquefaction.

Agar colonies: Yellow, raised, convex, spreading, entire.

Agar slant: Yellow, spreading.

Broth: Turbid.

Litmus milk: Yellow ring or pellicle. Coagulated; peptonized.

Potato: Yellow, slimy, spreading.

Brain medium not blackened.

Blood serum liquefied.
Starch is hydrolyzed.
Non-pathogenic.
Anaerobic.
Optimum temperature 25°C.
Habitat: The cause of grape vine disease.

17. **Clostridium histolyticum** (Weinberg and Seguin) Bergey et al. (*Bacillus histolyticus* Weinberg and Seguin, Compt. Rend. Acad. d. Sciences, *163*, 1916, 449.)

Rods: 0.5 to 0.7 by 3.0 to 5.0 microns, occurring singly and in pairs. Motile with peritrichous flagella. Spores oval, central. Gram-positive.

Gelatin: Complete liquefaction in 48 hours.

Gelatin colonies: Thin, bluish, crenated.

Agar slant.

Broth: Turbid.

Litmus milk: Acid; coagulated; peptonized. Gas is formed.

Potato.

Acid in dextrose, levulose, galactose, mannose, maltose and glycerol. Slight acidity in melezitose, esculin and amygdalin.

Blood serum slowly liquefied with darkened fluid.

Brain medium blackened.

Egg-meat medium. No gas is formed. The meat is reddened and digestion is apparent in 24 hours. The meat is darkened in three days.

Cultures have nauseating odor.

Pathogenic for small laboratory animals. Causes local necrosis on injection into animals.

Anaerobic.

Optimum temperature 37°C.

Habitat: Isolated from war wounds. Induces necrosis of tissue.

18. **Clostridum sporogenes** (Metchnikoff) Bergey et al. (*Bacillus sporogenes* Metchnikoff, Ann. de l'Institut Pasteur, *22*, 1908, 929; Bergey et al., Manual, 1st ed., 1923, 329.)

Rods: 0.6 to 0.8 by 3.0 to 7.0 microns, with rounded ends, occurring singly, less frequently in short chains. Motile with peritrichous flagella. Spores oval, central. Gram-positive.

Gelatin colonies: Liquefied.

Agar colonies: Small, irregular, transparent, becoming opaque, yellowish-white, fimbriate.

Agar slant: Grayish, opaque, spreading.

Broth: Turbid. Gas. Putrid odor.

Litmus milk: Coagulated. Litmus reduced. Slow peptonization, leaving dark amber-colored liquid.

Potato.

Indol formed (trace).

Nitrates not reduced.

Acid and gas in dextrose, levulose, galactose, maltose, dextrin, glycerol, mannitol and sorbitol.

Blood serum is liquefied, with dark putrid liquid.

Brain medium blackened.

Egg-meat medium: Gas is produced in eight hours. The meat becomes red and the liquid turbid. Digestion with slight putrefactive odor.

Not pathogenic.

Anaerobic.

Optimum temperature 37°C. Can grow at 50°C.

Habitat: Isolated from intestinal contents. Soil.

19. **Clostridium tetani** (Nicolaier) Holland. (*Bacillus tetani* Nicolaier, Deutsche med. Wochenschr., *10*, 1884, 842, Holland, Jour. Bact., *5*, 1920, 215.)

Rods: 0.4 to 0.6 by 4.0 to 8.0 microns, occurring singly. Motile with peritrichous flagella. Spores spherical, terminal. Gram-positive.

Gelatin stab: Slowly liquefied.

Serum agar colonies: Small, transparent, villous to fimbriate margin.

Agar slant: Thin, transparent.

Broth: Slightly turbid. Gas.

Litmus milk: Slow precipitation of casein.

Potato.

No acid or gas formed in carbohydrate media.

Blood serum not liquefied.

Brain medium blackened.

Coagulated albumin slowly liquefied.

Pathogenic. Forms a highly poisonous exotoxin for which an antitoxin is prepared.

Anaerobic.

Optimum temperature 37°C.

Habitat: The cause of tetanus.

20. **Clostridium putrificum** (Bienstock) Bergey et al. (Bienstock, Zeitschr. f. Klin. Med., *8*, 1884; *Bacillus putrificus coli* Flügge, Die Mikroorganismen, 1886, 303; *Bacillus putrificus* Bienstock, Ann. de l'Institut Pasteur, *13*, 1899, 861; Bergey et al., Manual, 1st ed., 1923, 333.)

Rods: 0.6 to 0.8 by 5 to 6 microns, occurring singly and in chains. Motile with peritrichous flagella. Spores round or nearly so, terminal, large. Gram-positive.

Gelatin stab: Liquefied in 5 to 6 days.

Agar colonies: Small, circular, flat, slightly crenated.

Broth: Turbid, with putrid odor.

Litmus milk: Acid coagulation, followed by slow peptonization.

No action on carbohydrates.

Blood serum is liquefied. Gas.

Brain medium blackened.

Egg-meat medium: Slightly turbid liquid in three or four days. The meat is reddened in a week or ten days. Digestion takes place, accompanied by foul odor.

Non-pathogenic.

Anaerobic.

Optimum temperature 35° to 37°C.

Habitat: Intestinal canal.

21. **Clostridium tetanomorphum** (McIntosh and Fildes) Bergey et al. (*Bacillus tetanomorphus* McIntosh and Fildes, Med. Research Com., Special Report Series No. 12, 1917, 32; Bergey et al., Manual, 1st ed., 1923, 330; *Bacillus pseudotetani* Tavel, Cent. f. Bakt., *23*, 1898, 528.)

Rods, slender, with rounded ends, occurring singly. Motile with peritrichous flagella. Spores slightly oval, terminal. Gram-positive.

Gelatin stab: Slowly liquefied.

Agar colonies: Small, flat, irregularly circular, translucent, crenated.

Agar slant: Grayish, translucent.

Broth: Turbid.

Litmus milk: Unchanged; occasionally slight reduction of litmus.

Potato.

Acid and gas in dextrose; slight acidity in levulose, maltose and inositol. Lactose and salicin not fermented.

Blood serum not liquefied.

Brain medium not blackened.

Coagulated albumin not liquefied.

Egg-meat medium: Slight gas formation in 48 hours. White crystals are deposited.

Non-pathogenic.

Anaerobic.

Optimum temperature 30° to 35°C.

Habitat: Soil.

22. **Clostridium sphenoides** (Douglas et al.) Bergey et al. (*Bacillus sphenoïdes*, Douglas, Fleming and Colebrook, Med. Research Com., Special Report Series No. 39, 1919, 43; Bergey et al., Manual, 1st ed., 1923, 331.)

Rods, small, fusiform, occurring singly and in pairs. Motile. Spores spherical, terminal. Gram-positive.

Gelatin stab: Not liquefied.

Agar colonies: Circular, entire.

Agar slant.

Broth: Turbid.

Litmus milk: Acid, sometimes shows soft coagulum.

Potato.

Acid and gas in dextrose, galactose, maltose, lactose, salicin and isodulcitol.

Blood serum not liquefied.
Brain medium not blackened.
Coagulated albumin not liquefied.
Non-pathogenic.
Anaerobic.
Optimum temperature 30° to 35°C.
Habitat: Soil.

23. Clostridium filiformie Bergey et al. (*Bacillus regularis filiformis* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 229; Bergey et al., Manual, 1st ed., 1923, 331.)

Slender rods: 0.5 to 0.8 by 3.0 to 5.0 microns, occurring in chains. Non-motile. Gram-positive. Spores small, spherical, terminal.

Gelatin colonies: Deep colonies, small, gray, filamentous.
Gelatin stab: No liquefaction.
Dextrose agar colonies: Deep colonies, irregular, gray, translucent. filamentous.
Dextrose agar slant.
Broth: Turbid.
Litmus milk: Acid; coagulated.
Potato: Gray, filamentous.
Indol not formed.
Nitrates not reduced.
Acid and gas in dextrose and lactose.
Blood serum not liquefied.
Anaerobic, facultative.
Optimum temperature 22°C.
Habitat: Intestinal canal.

24. Clostridium alcaligenes Bergey et al. (*Bacillus anaerobicus alcaligenes* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 229; Bergey et al., Manual, 1st ed., 1923, 331.)

Long, slender rods, occurring singly, in pairs and short chains. Non-motile. Gram-positive. Spores are spherical, terminal.

Gelatin colonies: Small, white, irregular.
Gelatin stab: No liquefaction.
Dextrose agar colonies: Deep colonies, irregular, white, granular, entire.
Dextrose agar slant.
Broth: Turbid.
Litmus milk: Alkaline; coagulated.
Potato.
Indol is formed.
Nitrates not reduced.
Acid and gas in dextrose and lactose.
Cultures have odor of valerianic acid.
Blood serum not liquefied.
Non-pathogenic.

Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

25. **Clostridium botulinum** (Van Ermengem) Holland. (*Bacillus botulinus* Van Ermengem, Cent. f. Bakt., I Abt., *19*, 1896, 443; Holland, Jour. Bact., *5*, 1920, 215.)

Rods: 0.9 to 1.0 by 4.0 to 8.0 microns, with rounded ends, occurring singly and occasionally in short chains. Motile with peritrichous flagella. Spores oval, terminal. Gram-positive.
Gelatin stab: Liquefied and blackened.
Agar colonies: Flat, grayish, irregular, mottled.
Agar slant.
Broth: Turbid.
Litmus milk: Litmus reduced. No coagulation.
Potato.
Acid and gas in dextrose, maltose, sucrose, glycerol and starch. Lactose not fermented.
Coagulated albumin liquefied.
Blood serum is liquefied.
Brain medium blackened.
Pathogenic for animals. Forms an exotoxin for which an antitoxin is prepared.
Anaerobic.
Optimum temperature 35° to 37°C. Can grow at 50°C.
Habitat: The cause of botulism. Filtrate is toxic for guinea pigs on feeding.

Note: Burke (Jour. Bact., *4*, 1919, 556) divided the species *Clostridium botulinum* into two types (Type A and Type B), because he found that the antitoxins of these types, while neutralizing their own toxins failed to neutralize the toxins of the other.

Bengtson (U. S. Pub. Health Service, Hyg. Lab., Bull. 136, 1924, 25) has added a third type (Type C) the toxin of which can not be neutralized by the antitoxin of either types A or B.

26. **Clostridium tyrosinogenes** (Hall) Bergey et al. (*Bacillus tyrosinogenes* Hall, Abst. Bact., *6*, 1922, 6; Bergey et al., Manual, 1st ed., 1923, 329.)

Rods: Motile. Spores subterminal. Gram positive.
Gelatin liquefied.
Agar colonies.
Agar slant.
Broth: Turbid.
Litmus milk.
Potato.
Indol not formed.
Nitrates not reduced.
Acid in monosaccharides.

Blood serum, liquefied. Forms large amounts of tyrosin which precipitates out in the cultures.

Liquefies coagulated albumin.

Brain medium blackened.

Non-pathogenic.

Anaerobic.

Optimum temperature.

Habitat.

27. **Clostridium tertium** (Henry) Bergey et al. (*Bacillus tertius* Henry, Jour. of Path. and Bact., *21*, 1916, 13; Bergey et al., Manual, 1st ed., 1923, 332.)

Rods: 0.4 to 0.6 by 3.0 to 6.0 microns, occurring singly. Slightly motile. Spores oval, terminal. Gram-positive.

Gelatin stab: Not liquefied.

Agar colonies: Circular with opalescent, crenated margin.

Agar slant: Grayish, opalescent growth.

Broth: Turbid, with sediment.

Litmus milk: Acid, coagulated, with some gas formation.

Potato.

Acid and gas in dextrose, levulose, galactose, mannose, lactose, maltose, sucrose, arabinose, xylose, trehalose, melezitose, soluble starch, esculin, glycerol, mannitol, inositol and salicin. No acid or gas in inulin or glycerol.

Blood serum liquefied. Gas.

Brain medium not blackened.

Egg-meat medium: Gas bubbles in eight hours. The meat is reddened and the liquid becomes turbid. There is slight digestion.

Non-pathogenic.

Anaerobic.

Optimum temperature 30° to 35°C. Can grow at 50°C.

Habitat: Isolated from war wounds.

28. **Clostridium fissus** (Debono) Bergey et al. (*Bacillus fissus* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 232; Bergey et al., Manual, 1st ed., 1923, 332.)

Long, slender rods, occurring singly and in chains. Motile. Gram-positive. Spores small, oval, terminal.

Gelatin colonies: Small, brownish.

Gelatin stab: No liquefaction.

Dextrose agar colonies: Deep colonies, white, globular.

Dextrose agar slant: Grayish streak.

Broth: Turbid.

Litmus milk: Acid; coagulated.

Potato.

Indol not formed.

Nitrates not reduced.

Acid and gas in dextrose, lactose, sucrose.

Produces butyric acid.
Blood serum not liquefied.
Non-pathogenic.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

29. **Clostridium flabelliferum** Sturges and Reddish. (Jour. of Bact., *11*, 1926, 37.)

Rods: 0.4 to 0.5 by 3.0 to 5.0 microns, with rounded ends, grouped in chains. Oval terminal spores of greater diameter than the rods. Motile. Gram-positive.

Gelatin: Rapid liquefaction.

Dextrose agar colonies: Surface-raised, with intertwining chains, Deep-globular, fimbriate.

Egg meat medium: Meat darkened and disintegrating. Disagreeable odor is formed.

Broth: Turbid, with flaky deposit.

Litmus milk: Soft coagulum is formed, which is quickly digested with dark amber fluid at top.

Acid and gas in dextrose, levulose, galactose, maltose and sucrose.
Non-pathogenic.
Anaerobic.
Optimum temperature 37°C.
Habitat: Isolated from "sour" ham and from salt.

30. **Clostridium caloritolerance** Meyer and Lang. (Jour. Infect. Dis., *39*, 1926, 321).

Rods: 0.5 to 0.8 by 8 to 10 microns, occurring in chains. Spores oval or pear-shaped, terminal. Motile with peritrichous flagella. Gram positive.

Gelatin stab: No liquefaction.

Surface colonies in dextrose agar: Small, flat, grayish, rhizoid.

Brain peptone mash with iron: Moderate gas formation with grayish discoloration of brain particles. Faintly putrefactive odor.

Broth: Turbidity, sedimentation and clearing.

Bromcresol purple milk: No change.

Indol is not formed.

Acid and gas in dextrose, galactose and maltose.
Blood serum not liquefied.
Anaerobic.
Optimum temperature 37°C.
Maximum survival time at 100°C. was 520 minutes.
Habitat: Soil.

31. **Clostridium cochlearum** (Douglas et al.) Bergey et al. (*Bacillus cochlearum* Douglas, Fleming and Colebrook. Med. Research Com., Special Report Series No. 39, 1919, 40; Bergey et al., Manual, 1st ed., 1923, 333.)

Rods, occurring singly. Motile with peritrichous flagella. Spores oval terminal. Gram-positive.

Gelatin stab: Not liquefied.

Agar colonies: Circular, clear, entire.

Agar slant.

Broth: Turbid.

Litmus milk: Unchanged.

Potato.

Does not ferment any of the carbohydrates.

Blood serum not liquefied.

Brain medium not blackened.

Non-pathogenic.

Anaerobic.

Optimum temperature 30° to 35°C.

Habitat: Soil.

32. **Clostridium regularis** Bergey et al. (*Bacillus sporogenes regularis* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 97; Bergey et al., Manual, 1st ed., 1923, 334.)

Large rods, with rounded ends, occurring singly. Motile. Gram-positive. Spores, large, oval, terminal.

Gelatin colonies.

Gelatin stab: Liquefied.

Dextrose agar colonies: Small, opaque, irregular.

Dextrose agar slant.

Broth.

Litmus milk: Acid; coagulated.

Potato.

Indol formed in small quantity.

Nitrates.

Slight acidity in dextrose, lactose and sucrose.

Slow peptonization of white of egg.

Non-pathogenic.

Anaerobic.

Optimum temperature 37°C.

Habitat: Intestinal canal.

33. **Clostridium saccharolyticum** Bergey et al. (*Bacillus sporogenes saccharolyticus* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 97; Bergey et al., Manual, 1st ed., 1923, 334.)

Short rods, with rounded ends, occurring singly and in pairs. Motile. Gram-positive. Spores, large, oval, terminal.

Gelatin colonies.

Gelatin stab: Liquefied.

Dextrose agar colonies: Gray, lenticular, entire.

Dextrose agar slant.

Broth: Turbid.

Litmus milk: Acid; coagulated; peptonized.
Potato.
Indol is formed.
Nitrates not reduced.
Acid and gas formed in dextrose and lactose.
White of egg is peptonized.
Non-pathogenic.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

34. **Clostridium filamentosum** Bergey et al. (*Bacillus putrificus filamentosus* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 97; Bergey et al., Manual, 1st ed., 1923, 333.)

Rods, slender, occurring singly and in chains. Motile. Gram-positive. Spores oval, terminal.
Gelatin colonies.
Gelatin stab: Liquefied.
Dextrose agar colonies.
Dextrose agar slant.
Broth: Turbid.
Litmus milk: Slightly acid.
Potato.
Indol not formed.
Nitrates not reduced.
Acid in dextrose.
White of egg liquefied
Non-pathogenic.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

35. **Clostridium zoogleicum** Bergey et al. (*Bacillus sporogenes zoogleicus* Distaso, Cent. f. Bakt., I Abt., Orig., *59*, 1911, 97; Bergey et al., Manual, 1st ed., 1923, 335.)

Short rods, occurring singly and in pairs. Motile. Gram-positive. Spores large, oval, terminal.
Gelatin colonies.
Gelatin stab: Liquefied.
Dextrose agar colonies: Small, gray, opaque.
Dextrose agar slant.
Broth: Turbid.
Litmus milk: Slow coagulation, with reduction of litmus.
Potato.
Indol not formed.
Nitrates not reduced.
Acid in dextrose.

White of egg is liquefied.
Non-pathogenic.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal. Resembles somewhat *Clostridium bifermentans* (Tissier and Martelly) Bergey et al.

36. **Clostridium coagulans** Bergey et al. (*Bacillus sporogenes coagulans* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 229; Bergey et al., Manual, 1st ed., 1923, 335.)

Straight rods: 0.8 by 1.0 to 3.0 microns, with rounded ends, occurring singly. Motile. Gram-positive. Spores oval, terminal, the organisms showing marked bulging.
Gelatin colonies: No growth.
Gelatin stab: Rapid liquefaction.
Dextrose agar colonies: Deep colonies, small, yellowish, becoming brownish, granular, fimbriate.
Dextrose agar slant.
Dextrose broth: Turbid.
Litmus milk: Coagulated; peptonized.
Potato.
Indol not formed.
Nitrates not reduced.
Acid and gas in dextrose. Forms butyric acid.
Cooked egg albumin is peptonized; odor of putrefaction.
Non-pathogenic.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

37. **Clostridium ovalaris** Bergey et al. (*Bacillus putrificus ovalaris* Debono, Cent. f. Bakt., I Abt., Orig., *62*, 1912, 229; Bergey et al., Manual, 1st ed., 1923, 336.)

Straight rods: 0.3 to 0.4 by 6.0 to 8.0 microns, with rounded ends, occurring singly and in short chains. Motile. Gram-positive. Spores oval terminal, the organism showing distinct bulging.
Gelatin stab: Rapid liquefaction.
Dextrose agar colonies: Small, globular, entire, becoming brownish.
Dextrose agar slant.
Broth: Turbid.
Litmus milk: Acid; peptonized.
Potato.
Indol not formed.
Nitrates not reduced.
Acid and gas in dextrose.
Egg albumin is slowly peptonized.
Odor of putrefaction.

Non-pathogenic.
Anaerobic.
Optimum temperature 37°C.
Habitat: Intestinal canal.

38. **Clostridium nigrificans** Werkman and Weaver. (Iowa State College, Jour. of Sci., *2*, 1927, 57.)

Rods: 0.5 by 3.0 to 6.0 microns, with rounded ends. Oval, terminal spores. Motile. Gram-positive.
Gelatin stab: No liquefaction.
Beef heart infusion agar colonies: No growth on plate cultures.
Shake cultures show black area around colonies.
Blood serum is not liquefied.
Indol not formed.
Nitrates not reduced.
No action on carbohydrates.
Anaerobic.
Optimum temperature 55°C.
Habitat: Isolated from spoiled canned foods. The cause of sulphur stinker spoilage.

39. **Clostridium werneri** Bergey et al. (*Bacillus cellulosam fermentans* Werner, Cent. f. Bakt., II Abt., *67*, 1926, 297; Bergey et al., Manual, 3rd ed., 1930, 452.)

Probable synonym: H_2S bacillus, Omelianski, Cent. f. Bakt., II Abt., *8*, 1902, 193; ibid., *11*, 1904, 369.
Rods: 0.5 to 0.7 by 1.5 to 7.0 microns. Spores oval, terminal, 1.0 to 1.2 by 1.5 to 2.0 microns. Motile with peritrichous flagella. Gram-negative.
Cellulose agar slant: Growth in contact with cellulose. Grayish-black. Gas is formed.
Agar slant: No growth.
Broth: No growth.
No action on sugars.
Cellulose digested with formation of H_2 and CO_2.
H_2S formed from $(NH_4)_2SO_4$ and from $MgSO_4$.
Anaerobic.
Optimum temperature 33° to 35°C.
Habitat: Isolated from larvae of roseleaf beetle. *Potosia cuprea* Fabr. Also from soil and feces of herbivorous animals.

40. **Clostridium felsinae** (Carbone and Tombolato) Bergey et al. (*Bacillus felsinus* Carbone and Tombolato, Le stazioni sperimentali agrarie italiane, *50*, 1917, 563; Ruschmann and Bavendamm, Cent. f. Bakt., II, *64*, 1925, 356; Bergey et al., Manual, 3rd ed., 1930, 353.)

Rods: 0.3 to 0.4 by 3.0 to 5.0 microns, occurring singly, in pairs and in chains. Motile with peritrichous flagella. Spores oval, terminal. Gram-positive. Cells store volutin, glycocol.

Gelatin and dextrose gelatin are liquefied.

Starch and cellulose are hydrolyzed. Pectinase is formed.

Butyric acid is not formed in retting flax or in potato.

Produces an orange-yellow pigment in alkaline media, which apparently belongs to the carotin group. The pigment is not soluble in alcohol, ether, chloroform or benzol.

Anaerobic.

Optimum temperature 30°C.

Habitat: In retting flax.

41. **Clostridium oedematoides** Meleney et al. (*Bacillus oedematis sporogenes* Sordelli, Compt. rend. Soc. de Biol., *89*, 1923, 53; Meleney, Humphreys and Carp, Proc. Soc. Exp. Biol. and Med., *24*, 1927, 675; *Bacillus sordellii* Hall and Scott, Jour. Infect. Dis., *41*, 1927, 329.)

Rods: 1.2 by 1.5 to 8.0 microns with rounded ends, occasionally growing out into long filaments. Young cultures are slightly motile. Spores oval, subterminal, with slight swelling of the rods. Gram positive.

The colonies in meat infusion agar are quite variable, ranging from solid, lenticular, spherical to irregularly shaped, with fluffy margin.

Gelatin is liquefied with formation of black sediment.

Brain medium is blackened.

Loffler's blood serum is slowly digested.

Litmus milk is slowly acidified with a soft coagulum and slow peptonization. Gas is formed.

Acid and gas are formed from dextrose, levulose and maltose. No action occurs with galactose, arabinose, lactose, sucrose, salicin, inulin, glycerol or mannitol.

A specific exotoxin is formed.

Anaerobic.

Optimum temperature 37°C.

Habitat: Encountered in malignant edema in man. Characteristic lesions are produced in guinea pigs on inoculation; as massive edema without gas formation, hemorrhage or necrosis.

42. **Clostridium spermoides** (Vinni) Bergey et al. (*Bacillus spermoides* Vinni, Pathologica, *21*, 1920, 385; Bergey et al., Manual, 1st ed., 1923, 336.)

Rods with elongate terminal spores. Non-motile.

Gelatin is liquefied.

Agar colonies.

Agar slant

Broth.

Litmus milk.

Potato.

Indol not formed.

Nitrates not reduced.

Blood serum is softened.

Brain medium blackened.

Non-pathogenic.
Anaerobic.
Optimum temperature 25° to 30°C.
Habitat: Soil. Not pathogenic.

43. **Clostridium thermochainum** Damon and Feirer. (Jour. of Bact., *10*, 1925, 42.)

Rods: 1.8 to 7.0 microns at 55°C. with rounded ends and granular cytoplasm. Occur singly and in short chains. Oval, terminal spores. Non-motile. Gram-positive.
Gelatin: No liquefaction.
Agar shake cultures: Round, with entire margin.
Cooked meat medium: No change in color. No digestion. Gas is formed.
Sugar-free meat medium: Reddened, with hazy growth.
Indol not formed.
Nitrates reduced to nitrites.
Fermentation: Dextrose, maltose, glycerol, mannitol and inulin are not attacked. Slight acidity in sucrose and starch but no gas.
H_2S not formed from lead acetate.
Thermal death point between 110° and 120°C. for 10 minutes.
Anaerobic.
Grows at 55°C.
Habitat: Horse feces.

44. **Clostridium thermoacidophilum** Damon and Feirer. (Jour. of Bact., *10*, 1925, 41.)

Rods: 1.2 by 10.8 microns in meat culture at 55°C., with rounded ends and granular cytoplasm. Oval, terminal spores. Non-motile. Gram-positive.
Gelatin: No liquefaction.
Agar shake colonies: Globular, with ciliate margin.
Cooked meat medium: No change in color. No digestion. Gas is formed.
Sugar-free meat medium: Reddened with hazy growth.
Indol not formed.
Nitrates reduced to nitrites.
Fermentation: Dextrose, lactose and maltose are not attacked.
Acid but no gas formed in sucrose, glycerol and starch. Acid and gas formed in mannitol and inulin.
H_2S not formed from lead acetate.
Thermal death point between 110° and 120°C. for 10 minutes.
Anaerobic.
Grows at 55°C.
Habitat: Horse manure.

45. **Clostridium thermoputrificum** Damon and Feirer. (Jour. of Bact., *10*, 1925, 39.)

Rods with homogeneous cytoplasm and rounded ends. The average dimensions in 48-hour chopped meat culture grown at 55°C. are 2.5 by 5.0 microns. Oval, terminal spores. Non-motile. Gram-positive.

Gelatin: No liquefaction.

Agar shake colonies: Small, discus-shaped, with well-defined margin.

Cooked meat medium: Gas bubbles with strong putrefactive odor. Color of medium unchanged. Proteolysis.

Sugar-free cooked meat medium: Reddened with hazy, diffuse growth.

Indol not formed.

Nitrates not reduced.

Fermentation: Dextrose, lactose and starch are not attacked. Sucrose, maltose, glycerol, mannitol and inulin are fermented at 37° to 55°C. with formation of gas but no acid.

H_2S formed in lead acetate infusion agar.

Anaerobic.

Grows well at 37° to 55°C. Thermal death point between 110° and 120°C. for 10 minutes.

Habitat: Well-rotted manure.

46. **Clostridium thermoaerogenes** Damon and Feirer. (Jour. of Bact., *10*, 1925, 40.)

Rods: 1.8 by 7.0 microns in meat culture grown at 55°C. with rounded ends and granular cytoplasm. Oval terminal spores. Non-motile. Gram-negative in 48-hour cultures.

Gelatin: No liquefaction.

Agar shake colonies: Round with well-defined margin.

Cooked meat medium: Color unchanged. Gas in two days. No odor. No proteolysis.

Sugar-free cooked meat: Reddened. Hazy growth throughout.

Indol not formed.

Nitrates reduced to nitrites.

Fermentation: Dextrose, lactose, sucrose, glycerol and mannitol are not attacked. Gas but no acid formed in maltose and inulin. Gas and acid formed in starch.

H_2S not formed from lead acetate.

Anaerobic.

Grows well at 55°C. Thermal death point between 110° and 120°C. for 10 minutes.

Habitat: Horse manure.

47. **Clostridium luciliae** Bengston. (U. S. Public Health Reports, *37*, 1922, 164.)

Rods: 0.5 to 0.8 by 3.0 to 6.0 microns, usually occurring singly, occasionally in short chains. Non-motile. Spores oval, terminal, of slightly greater diameter than the rods. Gram-positive.

Gelatin: Scant growth. No liquefaction.

Litmus milk: Acid reaction. No coagulation. No digestion.

Agar stab: Scant growth. No gas.

Dextrose agar shake cultures: At first lenticular colonies, but later becoming fluffy.

Meat hash medium: Slightly turbid with numerous gas bubbles.

Acid formed in dextrose but not in lactose and sucrose. No gas is formed in dextrose media.

Liver broth: Good growth with gas formation.

Pathogenic. Forms an exotoxin.

Anaerobic.

Optimum temperature 37°C.

Habitat: Larvae of *Lucilia caesar*. Produces limberneck in chickens. Toxin is not neutralized by botulinus antitoxin.

48. **Clostridium dissolvens** (Khouvine) Bergey et al. (*Bacillus cellulosae dissolvens* Khouvine, Ann. d. l'Institut Pasteur, *37*, 1923, 711; Bergey et al., Manual, 2nd ed., 1925, 334.)

Slender rods ranging from 2.5 to 12.5 microns in length, occurring singly, occasionally in pairs. Non-motile. Spores oval, terminal. Gram-positive.

It digests cellulose by forming an endocellulase which acts only when the bacteria are attached to cellulose. It forms saccharides from cellulose, also CO_2, H_2, ethyl alcohol, acetic and butyric acids. Does not ferment the simple carbohydrates.

A yellow pigment is formed.

Non-pathogenic.

Anaerobic.

Optimum temperature 33°C.

Habitat: Intestinal tract of man.

49. **Clostridium putrefaciens** (McBryde) *comb. nov.* (*Bacillus putrefaciens* McBryde, Bur. Am. Industry, U. S. Dept. Agr., Bull. 132, 1911; Sturges and Drake, Jour. Bact., *14*, 1927, 175.)

Rods, 0.5 to 0.7 by 3 to 15 microns, with rounded ends, occurring singly and in chains. Spores oval terminal 1.1 by 1.6 microns. Non-motile. Gram positive.

Gelatin stab: Liquefaction.

Agar colonies: Small, filamentous.

Agar slant: Scanty, white, beaded, glistening.

Broth: Moderate turbidity. Heavy, flocculent sediment.

Minced pork: Slight disintegration, sour, putrefactive odor.

Litmus milk: Coagulated, peptonized. Litmus reduced.

Indol not formed.

Nitrates not reduced.

Starch not hydrolyzed.

Slight production of H_2S.

Acid and gas in dextrose. Lactose, sucrose and maltose are not attacked.

Non-pathogenic.

Strict anaerobic.

Optimum temperature 20°–25°C. Slow growth at 0°C. and visible growth at 37°C.

Habitat: Isolated from muscle tissue of hogs at slaughter.

ORDER II. ACTINOMYCETALES BUCHANAN, 1918.

Cells usually elongated, frequently filamentous and with a decided tendency to the development of branches, in some genera giving rise to the formation of a definite branched mycelium. Cells frequently show swellings. clubbed or irregular shapes. No pseudoplasmodium. No deposits of free sulfur or iron. No bacteriopurpurin. Endospores not produced but conidia are developed in some genera. Usually Gram-positive. Non-motile. Some species parasitic in animals or plants. As a rule strongly aerobic (except for some species of *Actinomyces* and the genera *Fusiformis* and *Leptotrichia*) and oxidative. Complex proteins frequently required. Growth on culture media often slow; some genera showing mold-like colonies. No water forms.

Key to the families of the order **Actinomycetales.**

A. Filamentous forms, often branched, sometimes forming mycelium. Conidia sometimes present. Some species parasitic.

Family I. *Actinomycetaceae*, p. 495.

B. Parasitic forms. Rod-shaped, rarely filamentous, and with only slight and occasional branching. No conidia formed.

Family II. *Mycobacteriaceae*, p. 534.

FAMILY I. ACTINOMYCETACEAE BUCHANAN, 1918.

Filamentous forms often branched and sometimes forming mycelium. Conidia sometimes present. Some species are parasitic.

Key to the genera of family **Actinomycetaceae.**

A. Parasitic forms.

a. Anaerobic or facultative.

Genus I. *Leptotrichia*, p. 495.

B. A few parasitic forms; mostly soil forms.

a. Filamentous, often branched, sometimes forming mycelium.

Genus II. *Actinomyces*, p. 497.

b. Rods forming long filaments which rarely show branching.

Genus III. *Erysipelothrix*, p. 533.

Genus I. **Leptotrichia** *Trevisan, 1879.*

Thick, long, straight or curved filaments, unbranched, frequently clubbed at one end and tapering to the other. Gram-positive when young.

Filaments fragment into short, thick rods. Anaerobic or facultative. No aerial hyphae or conidia. Parasites or facultative parasites.

The type species is *Leptotrichia buccalis* (Robin) Trevisan.

1. **Leptotrichia buccalis** (Robin) Trevisan. (*Leptothrix buccalis* Robin, Histoire naturelle des végétaux parasites, Paris, 1853, 345; Trevisan, Reale Instituto Lombardo di Scienze e Lettere, *4*, 1879; *Rasmussenia buccalis* de Toni and Trevisan, Saccardo, Sylloge Fungorum, *8*, 1889, 930; *Bacterium buccale* Migula, System der Bakterien, 1900, 445; Probably *Leptothrix innominata* Chester, Manual Determ. Bact., 1901, 371; Not *Leptothrix buccalis* Chester, ibid., 371; Not *Bacillus buccalis* Chester, ibid., 234.)

Rods: 1.0 to 1.5 by 1.6 to 2.0 microns, frequently in long chains, often with partition walls. Non-motile.

Gelatin colonies: Circular, grayish-white, translucent.

Gelatin stab: Liquefaction crateriform.

Agar slant: White, translucent, becoming yellow, dry.

Broth: Flocculent and granular sediment.

Litmus milk: Unchanged.

Potato: Dirty, white, flat, spreading.

No gas in dextrose.

Indol not formed.

Nitrates not reduced.

Anaerobic, facultative.

Optimum temperature 35° to 37°C.

Habitat: Oral cavity.

2. **Leptotrichia placoides** Bergey et al. (*Leptothrix placoides alba* Dobrzyniecki, Cent. f. Bact., *21*, 1897, 225; Bergey et al., Manual, 3rd ed., 193, 458.)

Long, tangled threads. Non-motile. Gram-positive.

Gelatin colonies: White, filamentous.

Gelatin stab: Slowly liquefied.

Agar colonies: Small, white, filamentous.

Agar slant: White, filamentous, adherent.

Broth: No growth.

Litmus milk.

Potato: No growth.

Indol.

Nitrates.

Blood serum is liquefied.

Aerobic, facultative.

Optimum temperature 18°C.

Habitat: Isolated from a filling in tooth canal.

Genus II. Actinomyces *Harz, 1877.*

Organisms growing in form of a much-branched mycelium, which may break up into segments that function as conidia. Sometimes parasitic,

with clubbed ends of radiating threads conspicuous in lesions in the animal body. Some species are microaerophilic or anaerobic. Non-motile.

The type species is *Actinomyces bovis* Harz.

Key to the species of genus Actinomyces.

A. Animal parasites.
  1. In the animal body filaments show clavate enlargements at the ends.
    a. Show proteolytic action in coagulated albumin, fibrin, milk and gelatin.
      1. *Actinomyces bovis.*
    aa. Show strong proteolytic action in milk and gelatin.
    b. Form no pigment.
      2. *Actinomyces hominis.*
    bb. Form cream-yellow pigment.
      3. *Actinomyces madurae.*
    aaa. Show weak proteolytic action in gelatin.
    b. Form yellow-red pigment.
      4. *Actinomyces freeri.*
    aaaa. Show no proteolytic action.
    b. Form pale, straw-colored pigment.
      5. *Actinomyces actinoides.*
  2. Filaments without clavate enlargements.
    a. Show weak proteolytic action in gelatin.
    b. No pigment formed.
      6. *Actinomyces gedanensis.*
      7. *Actinomyces candidus.*
    aa. Show no proteolytic action in gelatin.
    b. Pigment formed.
    c. Pigment yellow-red.
      8. *Actinomyces asteroides.*
    cc. Pigment yellow-white.
      9. *Actinomyces farcinicus.*
    bb. No pigment formed.
      10. *Actinomyces necrophorus.*
      11. *Actinomyces gonadiformis.*

B. Plant parasites.
  1. Tyrosinase reaction positive.
    a. Aerial mycelium gray-white.
      12. *Actinomyces scabies.*
    aa. Aerial mycelium green.
      13. *Actinomyces aerugineus.*
  2. Tyrosinase reaction negative.
    a. Coremia formation or non-characteristic.
      14. *Actinomyces intermedius.*

aa. No coremia formation or non-characteristic.
b. Grow well at 42°C.
15. *Actinomyces incanescens.*
bb. Grow well at 12°C.
16. *Actinomyces cretaceus.*
bbb. Grow well at 19° to 34°C.
c. Soluble brown pigment on potato.
d. Size of conidia 0.65 by 1.5 microns.
17. *Actinomyces xanthostromus.*
dd. Size of conidia 0.7 × 0.8 micron.
18. *Actinomyces annulatus.*
cc. No soluble pigment on potato.
d. Ocher-yellow growth; no aerial mycelium.
19. *Actinomyces albus* var. *ochraleuceus.*
dd. Green-black growth; aerial mycelium cream-colored.
20. *Actinomyces nigrificans.*

C. Saprophytes; psychrophilic to mesophilic.
1. No soluble pigment formed on gelatin or other media.
a. Proteolytic action strong in milk and gelatin.
b. Yellowish-green growth on starch with pinkish aerial mycelium.
21. *Actinomyces citreus.*
2. No pigment formed on starch media.
22. *Actinomyces actinomorphus.*
aa. Gelatin not liquefied.
b. Growth on agar, white.
23. *Actinomyces erythropolis.*
bb. Growth on agar pinkish-white.
c. Nitrates reduced to nitrites.
24. *Actinomyces crystallophagus.*
25. *Actinomyces agrestis.*
cc. Nitrates not reduced.
26. *Actinomyces convolutus.*
3. Soluble, yellow pigment on Ca-malate agar.
a. Proteolytic action strong in milk and gelatin.
b. Yellow pigment formed.
c. Cellulose decomposed.
d. Starch is hydrolyzed.
27. *Actinomyces cellulosae.*
cc. Cellulose not decomposed.
28. *Actinomyces parvus.*
4. Soluble brown pigment formed on synthetic agar.
a. Proteolytic action strong in milk and gelatin.
b. Yellowish-green pigment on potato.

c. Aerial mycelium white to gray.
d. Starch hydrolyzed.
29. *Actinomyces diastaticus.*

5. Greenish-yellow soluble pigment formed.
a. Proteolytic action strong in milk and gelatin.
b. Sulphur-yellow pigment on potato.
c. Aerial mycelium gray, powdery.
d. Starch is hydrolyzed.
30. *Actinomyces flavovirens.*

6. No soluble pigment formed.
a. Proteolytic action strong in milk and gelatin.
b. Yellowish pigment on potato.
c. Aerial mycelium thick, powdery, water-green.
d. Starch is hydrolyzed.
31. *Actinomyces griseus.*
cc. Aerial mycelium white.
d. Starch weakly hydrolyzed.
32. *Actinomyces griseoflavus.*
bb. Reddish-brown pigment on potato.
c. Aerial mycelium white.
d. Starch is not hydrolyzed.
33. *Actinomyces poolensis.*
bbb. Gray to sulfur yellow pigment on potato.
c. Aerial mycelium mouse-gray to light drab.
d. Starch is hydrolyzed.
34. *Actinomyces olivaceus.*
cc. No aerial mycelium.
d. Starch is hydrolyzed.
35. *Actinomyces microflavus.*
aa. Proteolytic action weak.
b. Soluble pigment formed on synthetic agar.
c. Pigment blue or blue-black.
36. *Actinomyces violaceus-caeseri.*
cc. Pigment brown to black.
37. *Actinomyces exfoliatus.*
38. *Actinomyces gelaticus.*
bb. No soluble pigment on synthetic agar.
c. Growth turning black; diastatic action strong.
d¹. Growth on synthetic agar scant with abundant spirals in aerial mycelium.
39. *Actinomyces rutgersensis.*
d². No spirals on synthetic agar; characteristic green-colored growth on protein-glycerin medium.
40. *Actinomyces lipmanii.*
d³. No spirals on synthetic agar; growth dark, almost black.
41. *Actinomyces halstedii.*

d4. Growth orange-colored.

42. *Actinomyces fradii.*

d5. Growth yellowish.

43. *Actinomyces alboflavus.*

d6. Growth rose to red; aerial mycelium white.

44. *Actinomyces albosporeus.*

d7. Growth red; aerial mycelium black.

e. Complete decomposition of cellulose; weakly diastatic.

45. *Actinomyces melanosporeus.*

ee. Incomplete decomposition of cellulose; strongly diastatic.

46. *Actinomyces melanocyclus.*

7. Soluble brown pigment formed in all media containing organic substances.

a1. Pigment deep brown (chromogenic type).

b. Brown pigment on tyrosin agar.

c. Pigment faint brown on organic media, becoming greenish-brown to black; reddish aerial mycelium on dextrose agar.

47. *Actinomyces olivochromogenus.*

cc. Aerial mycelium yellowish with gray margin; good diastatic action.

48. *Actinomyces diastatochromogenus.*

ccc. Aerial mycelium yellowish; diastatic action weak.

49. *Actinomyces flavochromogenus.*

a2. Growth and aerial mycelium green on synthetic agar.

50. *Actinomyces viridochromogenus.*

a3. Deep brown to black pigment on synthetic agar.

b. Orange-red on potato; no aerial mycelium on synthetic agar; growing feebly.

51. *Actinomyces purpeochromogenus.*

bb. Brown to black on potato; abundant cottony aerial mycelium on synthetic agar.

c. Brown ring on milk culture; coagulated; peptonized.

52. *Actinomyces pheochromogenus.*

cc. Black ring on milk; no coagulation; peptonization doubtful.

53. *Actinomyces aureus.*

a1. Red to rose-red pigment on dextrose, maltose, and starch agar.

54. *Actinomyces erythrochromogenus.*

a2. Lavender-colored aerial mycelium.

55. *Actinomyces lavendulae.*

a3. Growth on potato gray, with black center.

56. *Actinomyces reticuli.*

a4. Growth on potato cream-colored, becoming pink to dark red.

57. *Actinomyces reticulus-ruber.*

a5. Growth on potato greenish-olive.

b. Aerial mycelium straw-colored.

58. *Actinomyces flavus.*

bb. Aerial mycelium chrome-orange.

59. *Actinomyces ruber.*

8. Soluble brown pigment on organic media faint brown, golden yellow, or blue.

a[1]. Pigment blue, not always definite.

b. Soluble red, turning blue, pigment on synthetic agar.

60. *Actinomyces waksmanii.*

a[2]. Pigment at first green becoming brown; aerial mycelium usually absent.

61. *Actinomyces verne.*

a[3]. Pigment at first brown, later lost; aerial mycelium abundant, white.

62. *Actinomyces albus.*

a[4]. Pigment yellowish-green; growth on synthetic agar penetrating into medium, pink.

63. *Actinomyces californicus.*

a[5]. Pigment golden yellow; growth on synthetic agar yellow, with yellow soluble pigment.

64. *Actinomyces flaveolus.*

a[6]. Pigment brown (only on certain protein media, as gelatin, dextrose broth).

b. Grown on synthetic agar red to pink. Scant, white, aerial mycelium.

65. *Actinomyces bobili.*

bb. Growth on synthetic agar colorless; aerial mycelium thin, rose color.

66. *Actinomyces roseus.*

bbb. Growth on synthetic agar mouse gray; powdery aerial mycelium.

67. *Actinomyces griseolus.*

bbbb. Growth on synthetic agar white turning yellowish; aerial mycelium white.

68. *Actinomyces erythreus.*

D. Saprophytes; thermophilic.

1. Starch hydrolyzed.

69. *Actinomyces thermodiastaticus.*

2. Starch not hydrolyzed.

70. *Actinomyces nondiastaticus.*

1. **Actinomyces bovis** Harz. (In Bollinger Cent. f. med. Wissensch. *15*, 1877, 485; Jahrsb. Münch. Thierarzenei Schule, 1877, 781.)

Breed and Conn, Jour. of Bacteriology, *4*, 1919, 596, give the following as synonyms:

Discomyces bovis Rivolta, La clinica Veterinaria, *1*, 1878, 208; *Bacterium actinocladothrix* Afanasiev, St. Petersburger Med. Wochenschr., *13*, 1888, 84; *Nocardia actinomyces* Trevisan, I genere e le specie delle Batteriacee,

Milan, 1889, 9; *Streptothrix actinomyces* Rossi-Doria, Annali 1st. d'Igiene Speri., Univ. Roma, *1*, 1891, 405; *Cladothrix bovis* Macé, Traité de Bacteriologie, 2d ed., 1891, 666; *Oospora bovis* Sauvageau and Radais, Ann. de l'Institut Pasteur, Paris, *6*, 1892, 271; *Actinomyces bovis sulfureus* Gasperini, Cent. f. Bakt., I Abt., *15*, 1894, 684; *Nocardia bovis* Blanchard, Bouchard's Traité de Path. generale, *2*, 1896, 857; *Cladothrix actinomyces* Macé, Traité de Bacteriologie, 3d ed., 1897, 1038; *Streptothrix actinomycotica* Foulerton, The Lancet, *2*, 1899, 780; *Streptothrix bovis communis* Foulerton, Jour. Comp. Path. and Therap., *14*, 1901, 50; *Streptothrix bovis* Chester, Determinative Bacteriology, 1901, 361; *Sphaerotilus bovis* Engler, Syllabus der Pflanzenfamilien, 5 Aufl., 1907, 5.

Thin, branching filaments with branching hyphae, 0.4 to 0.6 micron in thickness. Large, club-shaped forms are seen in animal tissues. Gram-positive.

Gelatin stab: Gray to brownish surface growth. Slow liquefaction.

Synthetic agar: Restricted, yellowish aerial mycelium appears late, becoming light sulfur-yellow, powdery.

Starch agar: Dirty-yellow growth.

Dextrose agar: Restricted yellowish, becoming dark.

Plain agar: Abundant, cream-colored, becoming fawn-colored, brown or almost black.

Dextrose broth: Small, round, flaky masses in the bottom; thin yellowish pellicle.

Litmus milk: Thin, yellowish surface growth; peptonized in 40 days. No coagulation.

Potato: Abundant, wrinkled, gray to canary-yellow.

Nitrates reduced to nitrites.

Acid in dextrose, lactose, sucrose, maltose and glycerol.

No soluble pigment formed.

Peptonization of milk, fibrin, egg albumin and gelatin.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The cause of "actinomycosis" in cattle, swine, and may be transmitted to man.

2. **Actinomyces hominis** Boström. (Beiträge z. Path. Anat. u Allgem. Pathologie, *9*, 1890, 1.)

Straight mycelium with straight hyphae, showing branching. Club-shaped forms in tissues. Conidia formed. Gram-positive.

Gelatin stab: Abundant, cream-colored, spreading growth. Liquefaction occurs.

Synthetic agar: Thin, spreading, white, shading toward yellow, becoming brown. Aerial mycelium white with olive tinge.

Starch agar: Yellowish, spreading.

Plain agar: Yellowish growth.

Dextrose broth: Thick, orange-colored ring.

Litmus milk: Abundant, cream-colored surface growth; coagulated, peptonized, becoming alkaline.

Potato: Abundant, yellowish to orange, wrinkled, becoming brown.

Nitrates reduced to nitrites.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic and microaerophilic.

Optimum temperature 37°C.

Habitat: The cause of actinomycosis in man.

3. **Actinomyces madurae** (Vincent) Lehmann u. Neumann. (*Streptothrix madurae* Vincent, Ann. de l'Institut Pasteur, *8*, 1894, 129; *Oospora madurae* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 388; Lehmann u. Neumann, Atlas u. Grundriss d. Bakt. *2*, 1912, 150.)

Straight, branching mycelium and hyphae, occasionally a few open spirals are formed. The filaments are 1.0 to 1.5 microns in thickness. The ends break up into ovoid conidia 1.5 to 1.75 microns in size. Club-shaped forms develop in lesions. Gram-positive.

Gelatin stab: Cream-colored surface growth, becoming greenish. No liquefaction.

Synthetic agar: Cream-colored, spreading. Aerial mycelium thin, powdery, white.

Starch agar: Thin, spreading, transparent.

Dextrose agar: Thin, glistening, pinkish, spreading.

Plain agar: Abundant, cream-colored.

Broth: Slightly turbid, with large, globular masses.

Litmus milk: Cream-colored ring. Peptonization with slightly alkaline reaction. No coagulation.

Potato: Abundant, yellow, wrinkled, becoming orange to orange-red with whitish aerial hyphae.

Nitrates reduced to nitrites.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The cause of madura foot. Not pathogenic for animals.

4. **Actinomyces freeri** (Musgrave and Clegg) Bergey et al. (*Streptothrix freeri* Musgrave and Clegg, Philippine Jour. of Sci., Med. Sciences, *2*, 1907, 477; Bergey et al., Manual, 1st ed., 1923, 346.)

Filaments with sheath, branching. Many short forms are seen. Club-forms are seen in tissues. Acid-fast to a marked degree. Gram-positive.

Gelatin stab: No liquefaction.

Glycerol agar colonies: Raised, sometimes umbilicated, yellowish with pink periphery.

Agar slant: Smooth, white, glistening.

Broth: Flocculent pellicle which settles to the bottom.

Litmus milk: Dry, flat, flaky pellicle, becoming thicker, vermiform, yellowish. Slight reduction of litmus.

Potato: Luxuriant, raised, delicate pink, becoming yellow in center.

Nitrates not reduced.

The pigment formed is not soluble.

No peptonization of milk or gelatin.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Mycetoma. Transmissible to monkeys, dogs and guinea pigs.

5. **Actinomyces actinoides** (Th. Smith) Bergey et al. (*Bacillus actinoides* Th. Smith, Jour. of Exper. Med., *28*, 1918, 333; *Bacillus actinoides* Lehmann and Neumann, Bakt. Diag. 7 Aufl., 1927, 780; Bergey et al., Manual, 1st ed., 1923, 346.)

Slender rods, changing to spherical types in old cultures. In the condensation water in blood serum filamentous forms are developed. Club-shaped forms appear in the lungs of calves. Gram-negative.

Gelatin colonies: No growth.

Gelatin stab: No growth.

Agar colonies: Very minute, pale, straw-color.

Agar slant: Flocculent growth in water of condensation.

Broth: No growth.

Litmus milk: No growth.

Potato: No growth.

Blood serum: Flocculent growth in water of condensation.

Nitrates not reduced.

Microaerophilic.

Optimum temperature 37°C.

Habitat: In epidemic pneumonia of calves. Not pathogenic for laboratory animals.

6. **Actinomyces gedanensis** Scheele and Petruschky. (Verhandlungen des Kongresses f. innere Med., 1897, 550; *Streptothrix gedanensis* Löhlein, Zeit. f. Hyg., *63*, 1909, 11.)

Long branching filaments with conidia formation.

Gelatin stab: White, cretaceous, dry, stellate to globular surface growth. Slow liquefaction.

Agar colonies: Dry, white, stellate.

Agar slant.

Broth: Fine, white, flaky pellicle and sediment.

Litmus milk: Yellowish pellicle. No coagulation.

Potato: Slight growth.

Nitrates not reduced.

No soluble pigment formed.

Starch.

Aerobic.
Optimum temperature 37°C.
Habitat: Isolated from sputum of patient suffering from chronic lung disease.

7. **Actinomyces candidus** Petruschky. (Handb. d. pathogenen Mikroorganismen, II, 832.)
Long branching filaments with conidia formation.
Gelatin stab: White, cretaceous surface growth. Liquefied.
Glycerin agar slant: Moist, spreading, folded.
Plain agar slant: Cretaceous layer.
Broth: Pellicle and sediment.
Litmus milk: Yellowish pellicle. No peptonization.
Potato: White, spreading.
Nitrates not reduced.
No soluble pigment formed.
Starch.
Aerobic.
Optimum temperature 37°C.
Habitat: Lung in pulmonary tuberculosis.

8. **Actinomyces asteroides** Eppinger. (Zeigler's Beiträge z. path. anat., *9*, 1890, 287; *Cladothrix asteroides* Macé, Traité de Bacteriologie, 6th ed., *2*, 1912, 730.)
Straight, fine mycelium, 0.2 micron in thickness, which breaks up into small, coccoid conidia.
Gelatin stab: Yellowish surface growth. No growth in stab. No liquefaction.
Synthetic agar: Thin, spreading, orange. No aerial mycelium.
Starch agar: Restricted, scant, orange.
Plain agar: Much folded, light yellow, becoming deep yellow to yellowish-red.
Dextrose broth: Thin, yellowish pellicle.
Litmus milk: Orange colored ring. No coagulation. No peptonization.
Potato: Much wrinkled, whitish, becoming yellow to almost brick-red.
Nitrates reduced to nitrites.
No soluble pigment formed.
Proteolytic action doubtful.
Starch not hydrolyzed.
Aerobic.
Optimum temperature 37°C.
Habitat: Isolated from cerebral abscess in man. Also found in conditions resembling pulmonary tuberculosis. Transmissible to rabbits and guinea pigs but not to mice.

9. **Actinomyces farcinicus** (Trevisan) Gasperini. (*Nocardia farcinica* Trevisan, I generi e le specie delle Batteriacee, Milan, 1889, 9; Gasperini, Ann. Ist. d'Igiene, Roma, *2*, 1892, 222.)

Synonyms: Bacille du farcin Nocard, Ann. de l'Institut Pasteur, *2* 1888, 293; *Streptothrix farcinica* Rossi-Doria, Annali 1st d'Igiene Speri. Univ. Roma, *1*, 1891, 405; *Oospora farcinica* Sauvageau and Radais, Ann. Inst. Pasteur Paris, *6*, 1892, 248; *Actinomyces bovis farcinicus* Gasperini, Cent. f. Bakt., I Abt., *15*, 1894, 684; *Cladothrix farcinica* Macé, Traité de Bacteriologie, 3rd ed., 1894, 1047; *Streptothrix farcini bovis* Kitt, Bacterienkunde und pathologische Microskopie, 3 Aufl., Vienna, 1899, 511; *Streptothrix nocardii* Foulerton, Jour. Compt. Path. and Therap., *14*, 1901, 51; *Discomyces farcinicus* Gedoelst, Les champignons parasites d l'homme et des animaux domestiques, Brussels, 1902, 167; *Actinomyces nocardii* Buchanan, Veterinary Bacteriology, Philadelphia, 1911, 378.

Filaments 0.25 micron in thickness, branched. Markedly acid-fast.

Gelatin colonies: Small, circular, transparent, glistening.

Gelatin stab: No liquefaction.

Agar colonies: Yellowish-white, irregular, refractive, filamentous.

Agar slant: Grayish to yellowish-white, surface roughened.

Broth: Clear, with granular sediment, often with gray pellicle.

Litmus milk: Unchanged.

Potato: Abundant, dull, crumpled, whitish-yellow.

Nitrates not reduced.

No soluble pigment formed.

Proteolytic action absent.

Starch not hydrolyzed.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Associated with disease in cattle, resembling chronic tuberculosis. Transmissible to guinea pigs, cattle and sheep, but not to rabbits, dogs, horses or monkeys.

10. **Actinomyces necrophorus** (Flügge) Lehmann u. Neumann. (Bacillus der Kälber-diphtherie, Loeffler, Mitteilungen a. d. Kaiserlich. Gesundheitsamte, *2*, 1884, 493; *Bacillus diphtheria vitulorum* Flügge, Die Microorganismen, 1886, 265; *Bacillus necrophorus* Flügge, *ibid.*, 273; *Bacillus filiformis* Schütz (not *Bacillus filiformis* Migula System der Bakterien, 1900, 587; not *Bacillus filiformis* Tils, Zeitsch. f. Hyg., *9*, 1890, 317); Necrosis-bacillus, Bang, Maanedskrift for Dyrleager, *2*, 1890, 235; *Streptothrix cuniculi* Schmorl, Deut. Zeitsch. f. Thermed., *17*, 1891, 376; *Actinomyces cuniculi* Gasperini, Mittheil. a. d. 11 Intern. Med. Cong. Rome. Also Cent. f. Bakt., *15*, 1894, 684; *Oospora diphtheria vitulorum* Lehmann and Neumann, Bakt. Diag. Aufl., *2*, 1896, 393; *Actinomyces necrophorus* Lehmann and Neumann, Bakt. Diag., 2 Aufl., *2*, 1899 (Eng. ed., *2*, 1901, 456); *Streptothrix necrophora* Kitt, Bakterienkunde, 1899; *Corynebacterium necrophorum*, Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 531; *Cladothrix cuniculi* Macé, Traité de Bacteriologie, 6th ed., *2*, 1913, 753; *Bacterium necrophorum* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 504.)

Rods: 0.5 to 1.5 microns wide, forming long filaments, up to 80 to 100 microns long, occasionally showing branching. Gram-negative.

Gelatin stab: No liquefaction.

Agar colonies: Small, dirty-white, circular, opaque, with yellowish center under low power lens. Margin floccose.

Agar stab: Yellowish colonies along needle track. Gas bubbles produced.

Blood serum: Small, whitish colonies, becoming opaque, fimbriate.

Broth: Turbid, with gas. Cheese-like odor.

Litmus milk: Cheese-like odor.

Indol is formed.

Nitrates not reduced.

Anaerobic.

Optimum temperature 37°C.

Habitat: Causes "diphtheria" in cattle with multiple sclerotic abscesses; gangrenous dermatitis in horses and mules; multiple necrotic foci in liver of cattle and hogs. One case of human infection reported. Transmissible to mice and rabbits.

11. **Actinomyces gonadiformis** (Tunnicliff and Jackson) Bergey et al. (*Bacillus gonadiformis* Tunnicliff and Jackson, Jour. of Infect. Dis., *36*, 1925, 430; Bergey et al., Manual, 3rd ed., 1930, 469.)

Pleomorphic rods with rounded ends, 0.5 by 1.0 to 3.0 microns, showing red granules with Giemsa stain. Gonidia form within the rods, developing into short or long wavy filaments. Non-motile. Gram-negative.

Gelatin: No growth.

Blood agar colonies: Thick, whitish, moist, entire.

Broth: Slight development, flocculent sediment.

Litmus milk: No growth.

Potato: No growth.

Acid and gas in dextrose.

Anaerobic.

Optimum temperature 37°C.

Habitat: Isolated from diseased tonsil.

12. **Actinomyces scabies** (Thaxter) Güssow. (*Oospora scabies* Thaxter, Ann. Rep. Com. Agr. Exp. Sta., 1891, 153; Güssow, Science, N. S., *39*, 1914, 431.)

Wavy or slightly curved mycelium, with long branched aerial hyphae, showing a few spirals. Conidia more or less cylindrical; 0.8 to 1.0 by 1.2 to 1.5 microns.

Gelatin stab: Cream-colored surface growth, becoming brown. Slow liquefaction.

Synthetic agar: Abundant, cream-colored, wrinkled, raised. Aerial mycelium white, scarce.

Starch agar: Thin, transparent, spreading.

Dextrose agar: Restricted, folded, cream-colored, entire.

Plain agar: Circular, entire colonies, smooth, becoming raised, lichinoid, wrinkled, white to straw-colored, opalescent to opaque.

Dextrose broth: Ring in form of small colonies, settling to the bottom.

Litmus milk: Brown ring with greenish tinge; coagulated; peptonized with alkaline reaction.

Potato: Gray, opalescent, becoming black, wrinkled.

Nitrates reduced to nitrites.

Brown soluble pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Cause of "potato scab" in the United States; found in soil.

13. **Actinomyces aerugineus** Wollenweber. (Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 13.)

Conidia 0.9 by 1.25 microns.

Growth on sterilized potato is yellow to brown, with a green aerial mycelium, the medium being colored black.

Odor: Characteristic soil odor.

Habitat: Deep scab on potato.

14. **Actinomyces intermedius** (Krüger) Wollenweber. (Berichte der Versuchsstat f. Zuckerrohrs, Kergok-Tegal, 1890; Wollenweber, Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 13.)

Conidia 0.7 by 0.9 micron.

Growth on potato olive green to olive brown, with light green to gray aerial mycelium. Medium olive color.

Odor: Characteristic soil odor.

Habitat: Soil of potato fields.

15. **Actinomyces incanescens** Wollenweber. (Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 13.)

Conidia 0.75 by 1.25 microns.

Growth on potato ocher-brown, with light lead-gray aerial mycelium; medium dark violet.

Habitat: Deep scab on potato.

16. **Actinomyces cretaceus** (Krüger) Wollenweber. (Krüger, Berichte der Versuchsstat. f. Zuckerrohrs, Kergok-Legal, 1890; Wollenweber, Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 13.)

Conidia 0.65 by 1.0 micron.

Growth on potato olive green, medium olive.

Habitat: Scabby potatoes.

17. **Actinomyces xanthostromus** Wollenweber. (Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 13.)

Conidia 0.65 by 1.5 microns.

Growth on potato golden yellow, with cream-colored aerial mycelium; medium colored brown.

Habitat: Scabby potatoes.

18. **Actinomyces annulatus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 649.)

Conidia 0.7 by 0.8 micron.

Growth on potato brown with cream-colored aerial mycelium; medium colored brown.

Habitat: Dark colored potato stem.

19. **Actinomyces albus** var. **ochraleuceus** Wollenweber. (Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 13.)

Conidia 0.75 by 1.25 microns.

Growth on potato ocher yellow, with cream-colored aerial mycelium.

Habitat: Surface and deep scab of potato.

20. **Actinomyces nigrificans** (Krüger) Wollenweber. (Krüger, Berichte der Versuchsstat. f. Zuckerrohrs, Kergok-Legal, 1890; Wollenweber, Arbeiten d. Forschungsinstitut für Kartoffelbau, 1920, 13.)

Conidia 0.65 by 1.15 microns.

Growth on potato ocher to greenish-black; aerial mycelium cream-colored.

Odor: Characteristic soil odor.

Habitat: Surface scab on potato.

21. **Actinomyces citreus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 99.)

Filaments with long, narrow open spirals. Conidia spherical to oval 1.2 to 1.5 by 1.2 to 1.8 microns.

Gelatin stab: Yellowish, restricted surface growth. Liquefaction in 35 days.

Synthetic agar: Abundant, spreading, raised, wrinkled, citron-yellow. Aerial mycelium covering surface; citron yellow.

Starch agar: Abundant, yellowish-green.

Dextrose agar: Extensive, center elevated, glossy, olive-yellow, entire.

Plain agar: Restricted, cream-colored.

Dextrose broth: Thin, wide, yellow ring; flaky sediment.

Litmus milk: Cream-colored surface growth; coagulated; peptonized, becoming alkaline.

Potato: Thin, gray, wrinkled.

Trace of nitrate reduction to nitrite.

The pigment formed is not soluble.

Proteolytic action in milk and gelatin.

Starch hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

22. **Actinomyces actinomorphus** (Gray and Thornton) Bergey et al. (*Mycobacterium actinomorphum* Gray and Thornton Cent. f. Bakt., II Abt., *73*, 1928, 74; Bergey et al., Manual, 3rd ed., 1930, 471.)

Long branching rods: 0.5 to 0.8 by 2.0 to 10.0 microns. Non-motile. Gram-positive.

Gelatin colonies: Circular, white, fimbriate.

Gelatin stab: Saccate liquefaction.

Agar colonies: Circular, white, convex, granular, fimbriate.

Agar slant: Filiform, white, raised, rugose, fimbriate.

Broth: Turbid, with pellicle.

Litmus milk.

Potato.

Indol.

Nitrates reduced to nitrites.

Starch hydrolyzed.

Attacks phenol and naphthalene.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

23. **Actinomyces erythropolis** (Gray and Thornton) Bergey et al. (*Mycobacterium erythropolis* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 74; Bergey et al., Manual, 3rd ed., 1930, 472.)

Long, uneven rods, curved, branching, 0.8 by 6.0 to 11.0 microns. Non-motile. Gram-positive.

Gelatin colonies: Circular, white, flat, glistening, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular, white, convex, entire.

Agar slant: Filiform, white, flat, undulate.

Broth: Slight turbidity.

Litmus milk.

Potato.

Indol.

Nitrates not reduced.

Starch not hydrolyzed.

Attacks phenol.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

24. **Actinomyces crystallophagus** (Gray and Thornton) Bergey et al. (*Mycobacterium crystallophagum* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 74; Bergey et al., Manual, 3rd ed., 1930, 472.)

Long, curved and irregular, branching cells, 0.8 by 2.0 to 4.0 microns. Non-motile. Gram-positive.

Gelatin colonies: Circular, whitish, smooth, glistening, filamentous edge.

Gelatin stab: No liquefaction.

Agar colonies: Circular, whitish-pink, convex, edge fimbriate.
Agar slant: Filiform, pinkish-white, convex, smooth, glistening, fimbriate edge.
Broth: Turbid, with broken pellicle and granular sediment.
Litmus milk.
Potato.
Indol.
Nitrates reduced by some strains.
Starch not hydrolyzed.
No action in carbohydrate media.
Attacks phenol and naphthalene.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Soil.

25. **Actinomyces agrestis** (Gray and Thornton) Bergey et al. (*Mycobacterium agreste* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 74; Bergey et al., Manual, 3rd ed., 1930, 472.)
Rods, in older cultures coccoid forms. Non-motile. Gram-negative.
Gelatin colonies: Circular, pink, smooth, glistening, edge filamentous.
Gelatin stab: No liquefaction. Arborescent growth in stab.
Agar colonies: Circular, pink, convex or umbonate, smooth, glistening, edge filamentous.
Agar slant: Filiform, pink, convex, smooth, glistening, undulate to filamentous margin.
Broth: Turbid with pink pellicle.
Litmus milk.
Potato.
Indol.
Nitrates reduced to nitrites.
Acid formed in dextrose and glycerol.
Starch hydrolyzed.
Attacks phenol, cresol and naphthalene.
Aerobic, facultative.
Optimum temperature 20°C.
Habitat: Manure and soil.

26. **Actinomyces convolutus** (Gray and Thornton) Bergey et al. (*Mycobacterium convolutum* Gray and Thornton, Cent. f. Bakt., II Abt., *73*, 1928, 74; Bergey et al., Manual, 3rd ed., 1930, 473.)
Long, uneven-sided rods, curved and bent, 0.8 to 1.0 by 3.0 to 4.0 microns. Non-motile. Gram-positive.
Gelatin colonies: Irregular, pinkish-white, papillate, filamentous.
Gelatin stab: No liquefaction.
Agar colonies: Circular, white, raised, smooth, erose.
Agar slant: Filiform, pinkish-white, smooth, undulate.
Broth: Broken, pinkish pellicle, and granular sediment.

Litmus milk.
Potato.
Indol.
Nitrates not reduced.
Starch not hydrolyzed.
No acid in carbohydrate media.
Attacks phenol and naphthalene.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: Soil.

27. Actinomyces cellulosae Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Conidia almost spherical, 1.3 microns in diameter, often arranged in chains.

Gelatin colonies: Circular, yellowish.

Gelatin stab: Liquefied.

Plain agar: White aerial mycelium.

Ca-malate agar: Yellowish colonies; gray aerial mycelium. Soluble yellow pigment formed.

Dextrose agar: Abundant, gray aerial mycelium. Soluble yellow pigment.

Starch agar: Same as on dextrose agar. Dextrose broth: Coarse, flaky growth. Yellow pigment.

Litmus milk: Peptonized.
Potato: Light gray growth; gray aerial mycelium.
Nitrates show slight reduction.
Strong diastatic action. Aesculin is hydrolyzed.
Cellulose is decomposed.
Marked proteolytic action.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

28. Actinomyces parvus Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Conidia more or less oval, 1.6 microns.
Gelatin colonies: Circular, yellow.
Gelatin stab: Slow liquefaction.
Ca-malate agar: Small, yellow colonies with light yellow, aerial mycelium.
Dextrose agar: Same as on Ca-malate agar
Starch agar: Same as on Ca-malate agar.
Dextrose broth: Semi-spherical colonies in bottom of tube.
Litmus milk: Peptonized.
Potato.
Nitrate slightly reduced.
Moderate diastatic action.

Cellulose not decomposed.
Marked proteolytic action.
Aerobic.
Optimum temperature.
Habitat: Garden soil.

29. **Actinomyces diastaticus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 99.)

Filaments may show fine, long, narrow spirals. Conidia oval, 1.0 to 1.2 by 1.1 to 1.5 microns.

Gelatin stab: Liquefied with small, cream-colored flakes in liquid.

Synthetic agar: Thin, gray, spreading. Aerial mycelium white, becoming drab gray.

Starch agar: Thin, colorless, spreading.

Dextrose agar: Yellowish, spreading.

Plain agar: Cream-colored.

Dextrose broth: Gray ring with grayish colonies in bottom of tube.

Litmus milk: Brownish ring; coagulated; peptonized in 25 to 30 days, becoming faintly alkaline.

Potato: Abundant, wrinkled, cream-colored with greenish tinge.

Nitrates reduced to nitrites.

Brown to dark brown soluble pigment formed.

Proteolytic action in milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

30. **Actinomyces flavovirens** Waksman. (Actinomyces 128, Waksman, Soil Science, *8*, 1919, 117; Waksman in Bergey's Manual, 1st ed., 1923, 352.)

Large masses of minute tufts; the hyphae coarse, straight, short, relatively unbranched, beaded; open spirals may be produced in certain substances. Conidia spherical, oval to rod-shaped, 0.75 to 1.0 by 1.0 to 1.5 microns.

Gelatin stab: Yellowish-green surface pellicle, consisting of a mass of small colonies, on the liquefied medium.

Synthetic agar: Spreading deep into the substratum, yellowish with greenish tinge. Aerial mycelium, gray, powdery.

Starch agar: Greenish-yellow, spreading, developing deep into the medium.

Dextrose agar: Restricted, developing only to a very small extent into the medium, yellow, turning black, edge entire.

Plain agar: Yellowish; the reverse dark in center with yellowish zone and outer white zone.

Dextrose broth: Thick, sulfur-yellow pellicle or ring.

Litmus milk: Cream-colored to brownish ring; coagulated; peptonized,

becoming faintly alkaline.

Potato: Sulfur-yellow, wrinkled.

Only traces of nitrite is formed from nitrates.

Greenish-yellow soluble pigment formed.

Peptonization in milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

Note: The name of the above organism together with those of species 34, 38, 64, 67, and 68, given below are attributed to S. A. Waksman because of the fact that he originally proposed these binomials as is indicated by the note in the preface of the Manual, 1st ed., 1923, III.

31. **Actinomyces griseus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Branching filaments; a few spirals have been observed. Conidia rod-shaped to short cylindrical, 0.8 by 0.8 to 1.7 microns.

Gelatin stab: Greenish-yellow or cream-colored surface growth with brownish tinge. Rapid liquefaction.

Synthetic agar: Thin, colorless, spreading, becoming olive buff. Aerial mycelium thick, powdery, water-green.

Starch agar: Thin, spreading, transparent.

Dextrose agar: Elevated in center, radiate, cream-colored to orange, erose margin.

Plain agar: Abundant, cream-colored, almost transparent.

Dextrose broth: Abundant, yellowish pellicle with greenish tinge, much folded.

Litmus milk: Cream-colored ring; coagulated with rapid peptonization, becoming alkaline.

Potato: Yellowish, wrinkled.

Nitrates reduced to nitrites.

Proteolytic action in milk and gelatin.

The pigment formed is not soluble.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

32. **Actinomyces griseoflavus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Conidia oval, 1.2 microns.

Gelatin colonies: Yellowish.

Gelatin stab: Rapidly liquefied.

Plain agar: Colonies yellowish, with white aerial mycelium.

Ca-malate agar: Large colonies covered with yellow to greenish-gray aerial mycelium.
Dextrose agar: White aerial mycelium is slowly formed.
Starch agar: White aerial mycelium.
Dextrose broth: Flaky growth.
Litmus milk: Peptonized.
Potato: Yellowish, aerial mycelium gray.
Nitrates reduced to nitrites.
Weakly diastatic. Acts on aesculin.
Grows well on cellulose.
Strongly proteolytic.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

33. **Actinomyces poolensis** Taubenhaus. (Jour. of Agr. Research, *13*, 1918, 437.)
Fine, branching mycelium; spirals usually not seen. Conidia oval to elliptical.
Gelatin stab: Liquefied, with small, brownish flakes in fluid.
Synthetic agar: Thin, colorless, spreading. Aerial mycelium white to gray.
Starch agar: Restricted, cream-colored.
Dextrose agar: Abundant, light-brown, glossy, raised center, entire.
Plain agar: Yellowish, translucent.
Dextrose broth: Thin, brownish ring.
Litmus milk: Brownish ring; coagulated; peptonized, with strongly alkaline reaction.
Potato: Thin, reddish-brown; medium becoming purplish.
Nitrates reduced to nitrites.
Peptonization of milk and gelatin.
Faint trace of soluble brown pigment.
Starch not hydrolyzed.
Aerobic.
Optimum temperature 37°C.
Habitat: Associated with disease of sweet potato.

34. **Actinomyces olivaceus** Waksman. (Actinomyces 206, Waksman, Soil Science, 7, 1919, 117; Waksman in Bergey's Manual, 1st ed., 1923, 354.)
Small clumps, with straight and branching hyphae. No spirals on most media. Conidia spherical and oval, 0.9 to 1.1 by 0.9 to 2.0 microns.
Gelatin stab: Liquefied with cream-colored, flaky, yellow sediment.
Synthetic agar: Abundant, spreading, developing deep into medium, yellow to olive ocher, reverse yellow to almost black. Aerial mycelium mouse-gray to light drab.
Starch agar: Thin, yellowish-green, spreading.
Dextrose agar: Abundant, restricted, center raised, entire.

Plain agar: White, glistening.
Dextrose broth: Sulfur-yellow ring.
Litmus milk: Faint, pinkish growth; coagulated; peptonized, becoming alkaline.
Potato: Abundant, much wrinkled, elevated, gray, turning sulfur-yellow on edge.
Nitrates reduced to nitrites.
The pigment formed is not soluble.
Peptonization of milk and gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

35. **Actinomyces microflavus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)
Conidia large, spherical to rod-shaped, often in pairs or chains 2.0 by 2.0 to 5.0 microns.
Gelatin colonies: Small, yellow.
Gelatin stab: Liquefied.
Plain agar: Yellow colonies, with rose-yellow aerial mycelium in 3 to 4 weeks.
Ca-malate agar: Minute yellow colonies. No aerial mycelium.
Dextrose agar: A rose yellow aerial mycelium develops in about 12 days.
Starch agar: Same as on dextrose agar.
Dextrose broth: Small spherical colonies in depth.
Litmus milk: Peptonized.
Potato: Yellow growth. No aerial mycelium.
Nitrates reduced to nitrites.
Strongly diastatic.
Scant growth on cellulose.
Starch is hydrolyzed.
Strongly proteolytic.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

36. **Actinomyces violaceus-caeseri** Waksman and Curtis. (Soil Science, *1*, 1916, 111.)
Filaments with both straight and spiral aerial hyphae; spirals dextrose. Conidia oval to elongate.
Gelatin stab: Small, cream-colored surface colony with slow liquefaction.
Synthetic agar: Gray, becoming bluish, glossy, much wrinkled. Aerial mycelium appears late; white.
Starch agar: Restricted, circular, bluish-violet colonies.
Dextrose agar: Restricted, gray, becoming red.
Plain agar: Thin, cream-colored.

Dextrose broth: Fine, colorless, flaky sediment.

Litmus milk: Gray ring; coagulated; slow peptonization, becoming faintly alkaline.

Potato: Cream-colored, wrinkled, turning yellowish.

Nitrates reduced to nitrites.

Soluble purple pigment formed.

Slow peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

37. **Actinomyces exfoliatus** Waksman and Curtis. (Soil Science, *1*, 1916, 116.)

Slightly wavy filaments with tendency to form spirals. Conidia oval, 1.0 to 1.5 by 1.2 to 1.8 microns.

Gelatin stab: Cream-colored surface growth. Liquefied.

Synthetic agar: Colorless, becoming brown, smooth, glossy. Aerial mycelium in white patches over surface.

Starch agar: Restricted, gray, becoming brown.

Plain agar: Grows only in depth of medium.

Dextrose broth: Small, grayish colonies in depth.

Litmus milk: Cream-colored ring, soft coagulum in 12 days; slow peptonization, becoming strongly alkaline.

Potato: Somewhat wrinkled, gray, becoming brown.

Nitrates reduced to nitrites.

Brown, soluble pigment formed.

Slight peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

38. **Actinomyces gelaticus** Waksman. (Actinomyces 104, Waksman, Soil Science, *8*, 1919, 165; Waksman in Bergey's Manual, 1st ed., 1923, 356.)

Branching mycelium with open spirals.

Gelatin stab: Liquefied with cream-colored flaky sediment.

Synthetic agar: Colorless, spreading, chiefly deep into the medium. Aerial mycelium thin, white, turning grayish.

Starch agar: Thin, spreading, cream-colored.

Dextrose agar: Abundant, spreading, white.

Plain agar: Wrinkled, cream-colored growth only on the surface.

Dextrose broth: Thin, cream-colored pellicle; slight flaky sediment.

Litmus milk: Pinkish ring; coagulated; peptonized with distinctly alkaline reaction.

Potato: Abundant, much wrinkled, greenish, becoming black with yellowish margin.

Nitrates show slight reduction to nitrites.
Soluble brown pigment formed.
Peptonization of milk and gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

39. **Actinomyces rutgersensis** Waksman and Curtis. (Soil Science, *1*, 1916, 123.)

Branching filaments with abundant open and closed spirals; hyphae fine, long, branching. Conidia spherical and oval, 1.0 to 1.2 microns, with tendency to bipolar staining.

Gelatin stab: Cream-colored, spreading surface growth. Liquefied.

Synthetic agar: Thin, colorless, spreading, becoming brownish to almost black. Aerial mycelium thin, white, becoming dull-gray.

Starch agar: Gray, spreading.

Dextrose agar: Abundant, brown mycelium, becoming black with cream-colored margin.

Plain agar: Thin, wrinkled, cream-colored.

Litmus milk: Cream-colored ring; coagulated; slow peptonization, becoming alkaline.

Potato: Abundant, white-gray, much folded.
Nitrates reduced to nitrites.
The pigment formed is not soluble.
Peptonization of milk and gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 37°C.
Habitat: Soil, common.

40. **Actinomyces lipmanii** Waksman and Curtis. (Soil Science, *1*, 1916, 123.)

Straight, branching mycelium and hyphae. Conidia oval, 0.8 to 1.1 by 1.0 to 1.5 microns.

Gelatin stab: Liquefied with cream colored, flaky sediment.

Synthetic agar: Abundant, raised, colorless, becoming light brown and wrinkled. Aerial mycelium white, turning gray.

Starch agar: Transparent, becoming dark with age.

Dextrose agar: Light yellow, irregular, spreading.

Plain agar: Yellow, glossy, radiately wrinkled.

Dextrose broth: White ring, with abundant, colorless flaky sediment.

Litmus milk: Cream-colored ring; coagulated; peptonization with alkaline reaction.

Potato: Abundant, cream-colored, wrinkled.
Nitrates reduced to nitrites.
The pigment formed is not soluble.

Peptonization of milk and gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil, common.

41. **Actinomyces halstedii** Waksman and Curtis. (Soil Science, *1*, 1916, 124.)

Branching mycelium and hyphae with close spirals. Conidia oval or rod-shaped, 1.0 to 1.2 by 1.2 to 1.8 microns.

Gelatin stab: Liquefied, with small, cream-colored masses in bottom of tube.

Synthetic agar: Abundant, heavy, spreading, raised, light, becoming dark, almost black. Aerial mycelium white, turning dull-gray.

Starch agar: Abundant, brownish, glossy.

Dextrose agar: Spreading, colorless, wrinkled, center elevated, edge lichinoid, becoming brown.

Plain agar: Restricted, wrinkled, cream-colored.

Dextrose broth: Small, colorless colonies in bottom of tube.

Litmus milk: Cream-colored ring; coagulated; peptonized, becoming alkaline.

Potato: Abundant, moist, wrinkled, cream-colored with green tinge.
Nitrates reduced to nitrites.
Peptonization of milk and gelatin.
The pigment formed is not soluble.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 37°C.
Habitat: Soil.

42. **Actinomyces fradii** Waksman and Curtis. (Soil Science, *1*, 1916, 125.)

Straight, branching filaments and hyphae. No spirals. Conidia rod or oval shape, 0.5 by 0.7 to 1.25 microns.

Gelatin stab: Cream-colored to brownish, dense growth on liquid medium.

Synthetic agar: Smooth, spreading, colorless. Aerial mycelium thick, cottony mass covering surface, sea-shell pink.

Starch agar: Spreading, colorless.

Dextrose agar: Restricted, glossy, buff-colored, lichenoid margin.

Plain agar: Yellowish, becoming orange-yellow, restricted.

Dextrose broth: Dense, narrow, orange-colored ring; abundant, flaky, colorless sediment.

Litmus milk: Faint, cream-colored ring; coagulated; peptonized, becoming alkaline.

Potato: Restricted, orange-colored.
Nitrates not reduced.

The pigment formed is not soluble.
Peptonization of milk and gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

43. **Actinomyces alboflavus** Waksman and Curtis. (Soil Science, *1*, 1916, 120.)

Straight, branching mycelium, with very little tendency to form spirals. Very few oval-shaped conidia formed.

Gelatin stab: Abundant, colorless surface growth. Liquefaction occurs in 35 days.

Synthetic agar: Glossy, colorless, spreading, becoming yellowish. Aerial mycelium white, powdery, with yellow tinge.

Starch agar: Thin, yellowish, spreading.

Dextrose agar: Restricted, much-folded, creamy with sulphur-yellow surface.

Plain agar: Restricted, cream-colored.

Dextrose broth: White, cylindrical colonies on surface, later flaky mass in bottom of tube.

Litmus milk: Pinkish ring. No coagulation. Peptonized, becoming alkaline.

Potato: Moist, cream-colored, wrinkled.
Nitrates reduced to nitrites.
The pigment formed is not soluble.
Starch is hydrolyzed.
Peptonization of milk and gelatin.
Aerobic.
Optimum temperature 37°C.
Habitat: Soil.

44. **Actinomyces albosporeus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 649; Waksman and Curtis, Soil Science, *1*, 1916, 99.)

Straight, branching filaments with straight, branching hyphae, and occasional spirals. Conidia spherical or oval, 0.8 to 1.2 by 1.0 to 1.8 microns.

Gelatin stab: Yellow, changing to red, with hyaline margin. Liquefaction in 35 days.

Synthetic agar: Spreading, colorless with pink center, becoming brownish. Aerial mycelium white at first, later covering the surface.

Starch agar: Thin, spreading, transparent, with red tinge.

Dextrose agar: Spreading, red, wrinkled, radiate, entire.

Plain agar: Minute, cream-colored colonies.

Dextrose broth: Pinkish ring.

Litmus milk: Scant, pink ring. No coagulation. No peptonization.

Potato: Thin, spreading, wrinkled, gray, becoming brown with greenish tinge.

Nitrates reduced to nitrites.
The pigment formed is not soluble.
Proteolytic action in gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 37°C.
Habitat: Soil.

45. **Actinomyces melanosporeus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Conidia almost spherical, 1.2 microns in diameter.
Gelatin colony: Small, reddish colonies.
Gelatin stab: Liquefied.
Ca-malate agar: Colonies red, with black aerial mycelium.
Dextrose agar: Same as on Ca-malate agar.
Starch agar: Same as on Ca-malate agar.
Dextrose broth: Flaky, orange red colonies adherent to glass.
Litmus milk: Peptonized.
Potato: Red colonies with black aerial mycelium.
Nitrates reduced to nitrites.
Weakly diastatic.
Grows well on cellulose. Cellulose is decomposed.
Proteolytic.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

46. **Actinomyces melanocyclus** (Maerker) Krainsky. (*Micrococcus melanocyclus* Maerker, Cent. f. Bakt., II Abt., *31*, 1911, 589; Krainsky, Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Conidia almost spherical, 0.9 micron in diameter.
Gelatin colonies: Growth poor.
Gelatin stab: Rapid liquefaction.
Plain agar
Ca-malate agar: Colonies, small, flat, orange-red. Aerial mycelium black, occurring along the edges.
Dextrose broth: Same as on Ca-malate agar.
Starch agar: Same as on Ca-malate agar.
Dextrose broth: Colorless, spherical colonies.
Litmus milk: Peptonized.
Potato.
Nitrates reduced to nitrites.
Good diastatic action.
Cellulose is decomposed.
Strong proteolytic action.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

47. **Actinomyces olivochromogenus** Bergey et al. (*Actinomyces chromogenus 205*, Waksman, Soil Science, *8*, 1919, 106; Bergey et al., Manual, 2nd ed., 1925, 368.)

Filaments with numerous close spirals. Conidia oval or elliptical.

Gelatin stab: Cream-colored, spreading surface growth. Rapid liquefaction.

Synthetic agar: White, spreading. Aerial mycelium ash-gray with brownish tinge.

Starch agar: Transparent, spreading.

Dextrose agar: Abundant, natal brown to almost black, entire margin.

Plain agar: Wrinkled, brown, becoming gray-green.

Dextrose broth: Thin, brown, flaky sediment.

Litmus milk: Dark brown ring; coagulated; peptonized, becoming alkaline.

Potato: Small, wrinkled, black colonies.

Faint traces of nitrites formed from nitrates.

Soluble brown pigment formed.

Proteolytic action in milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

48. **Actinomyces diastatochromogenus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Conidia spherical or oval, about 1.2 microns.

Gelatin colonies: Light gray colored.

Gelatin stab: Liquefied.

Plain agar: Medium sized colonies, with white to gray aerial mycelium.

Ca-malate agar: Medium-sized colonies, colorless, with gray aerial mycelium.

Dextrose agar: Same as in Ca-malate agar.

Starch agar: Same as in Ca-malate agar.

Dextrose broth: Flaky colonies in depth at first, later also over surface.

Litmus milk.

Potato: Light gray colonies; gray aerial mycelium; medium colored black.

Soluble brown pigment formed in gelatin.

Weakly diastatic.

No growth on cellulose.

Strongly proteolytic.

Tyrosinase formed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

49. **Actinomyces flavochromogenus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Conidia oval, 1.7 microns.

Gelatin colonies: Yellowish colonies.

Gelatin stab: Slight liquefaction.

Plain agar: Aerial mycelium formed late, at first white, later gray. Gray soluble pigment formed.

Ca-malate agar: Colonies yellow with white aerial mycelium forming late.

Dextrose agar: Brown soluble pigment formed.

Starch agar: Yellow colonies, with white aerial mycelium.

Dextrose broth: Fine flakes, with small spherical colonies adherent to glass. Medium colored brown.

Litmus milk.

Potato: Yellow colonies, with white aerial mycelium.

Nitrates reduced to nitrites.

Weakly diastatic. Aesculin acted upon.

Slow growth on cellulose.

Weakly proteolytic.

Tyrosinase formed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

50. **Actinomyces viridochromogenus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 114.)

Filaments with numerous open spirals, 3 to 5 microns in diameter, occurring as side branches and terminal conidia, short ovals or spheres, 1.25 to 1.5 microns.

Gelatin stab: Cream-colored surface growth, becoming greenish. Slow liquefaction.

Synthetic agar: Spreading, cream-colored with dark center, becoming dark green; reverse yellowish to light cadmium. Aerial mycelium abundant, spreading, white, becoming light geladine green.

Starch agar: Circular, spreading, yellowish colonies.

Dextrose agar: Abundant, spreading, wrinkled, gray, becoming black.

Plain agar: Abundant, restricted, gray, with greenish tinge.

Dextrose broth: Dense, solid ring, brownish, becoming dark green.

Litmus milk: Dark, brown surface growth; coagulated; peptonized, with faintly alkaline reaction.

Potato: Abundant, gray-brown.

Nitrates reduced to nitrites.

Soluble brown pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

51. **Actinomyces purpeochromogenus** Waksman and Curtis. (Soil Science, *1*, 1916, 113.)

Branching mycelium and hyphae with few imperfect spirals. Conidia spherical, 0.75 to 1.0 micron in diameter.

Gelatin stab: Slow, brownish surface growth. Slow liquefaction.

Synthetic agar: Slow, restricted, smooth, center raised, gray, becoming brown with purplish tinge. Margin yellow.

Starch agar: Small, dark-brown colonies.

Dextrose agar: Abundant, restricted, gray, becoming brown to dark brown.

Plain agar: Gray to brownish, becoming dark brown, almost black.

Dextrose broth: Slight, flaky sediment.

Litmus milk: Dark-brown ring; coagulated; slowly peptonized, with faintly alkaline reaction.

Potato: Restricted, orange to orange-red.

Nitrates not reduced.

Soluble dark brown pigment formed.

Peptonization of milk and gelatin.

Starch shows slight hydrolysis.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

52. **Actinomyces pheochromogenus** Conn. (Tech. Bull. No. 60, N. Y. State Agr. Exp. Sta., 1917, 16.)

Branching filaments and hyphae, spirals narrow, open, elongated, sinistrorse.

Gelatin stab: Abundant, spreading, cream-colored surface growth, becoming brown. Slow liquefaction.

Synthetic agar: Colorless, becoming brown to almost black. Aerial mycelium abundant, white with brownish shade.

Starch agar: Spreading, brownish, becoming brown.

Dextrose agar: Restricted, much folded, brown.

Plain agar: Thin, cream-colored, becoming gray.

Dextrose broth: Dense, wrinkled pellicle.

Litmus milk: Dark, almost black ring; coagulated, with slow peptonization, faintly alkaline reaction.

Potato: Brown to almost black.

Nitrates reduced to nitrites.

Soluble brown pigment formed.

Slight peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

53. **Actinomyces aureus** Waksman and Curtis. (Soil Science, *1*, 1916, 124.)

Mycelium shows numerous spirals. Conidia spherical to oval, 0.6 to 1.0 by 0.8 to 1.4 microns.

Gelatin stab: Fair, cream-colored surface growth, becoming brown, spreading. Liquefied.

Synthetic agar: Thin, spreading, colorless. Aerial mycelium thin, gray, powdery, becoming cinnamon drab.

Starch agar: Thin, transparent, spreading.

Dextrose agar: Spreading, light orange, raised center, hyaline margin.

Plain agar: Restricted, gray.

Dextrose broth: Thin, brownish ring; flaky sediment.

Litmus milk: Black ring. No coagulation. Peptonization doubtful.

Potato: Abundant, wrinkled, brown, becoming black.

Nitrates reduced to nitrites.

Soluble brown pigment formed.

Slight peptonization of gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

54. **Actinomyces erythrochromogenus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Conidia oval, about 2.0 microns long.

Gelatin colonies: Slow growth.

Gelatin stab: Liquefied. A soluble brown pigment formed.

Plain agar: Brown soluble pigment. White aerial mycelium.

Ca-malate agar: Colonies circular, with grayish-white margined aerial mycelium.

Dextrose agar: Red pigment formed.

Starch agar: A soluble rose pigment on old cultures.

Dextrose broth: Abundant growth. Floating colonies, later a pellicle is formed. Brown soluble pigment.

Litmus milk.

Potato: Gray aerial mycelium. Medium colored black.

Nitrates show slight reduction.

Weakly diastatic.

No proteolytic enzyme formed.

No growth in cellulose.

Aerobic.

Optimum temperature 30°C.

Habitat: Soil and roots of Alnus.

55. **Actinomyces lavendulae** Waksman and Curtis. (Soil Science, *1*, 1916, 126.)

Mycelium and hyphae coarse, branching. Spirals close, 5 to 8 microns in diameter. Conidia oval, 1.0 to 1.2 by 1.6 to 2.0 microns.

Gelatin stab: Creamy to brownish surface growth. Liquefied.

Synthetic agar: Thin, spreading, colorless. Aerial mycelium cottony, white, becoming vinous-lavender.

Starch agar: Restricted, glistening, transparent.

Plain agar: Gray, wrinkled.

Dextrose broth: Abundant, flaky sediment.

Litmus milk: Cream-colored ring. No coagulation; peptonized, with strong alkaline reaction.

Potato: Thin, wrinkled, cream-colored to yellowish.

Nitrates reduced to nitrites.

Soluble brown pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

56. **Actinomyces reticuli** Waksman and Curtis. (Soil Science, *1*, 1916, 118.)

Mycelium in whirls; spirals formed on dextrose agar are sinistrorse. Conidia spherical 1.0 to 1.4 microns in diameter.

Gelatin stab: Liquefied with small, brown flakes.

Synthetic agar: Colorless, with yellowish tinge, becoming brownish, spreading. Aerial mycelium thin, white, cottony.

Starch agar: Brownish gray.

Dextrose agar: Restricted, brownish, center raised.

Plain agar: Gray, wrinkled, becoming brownish.

Dextrose broth: Sediment consisting of large colonies.

Litmus milk: Reaction unchanged; coagulated; peptonized.

Potato: Gray, with black center.

Nitrates reduced to nitrites.

Dark brown pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

57. **Actinomyces reticulus-ruber** Waksman. (*Actinomyces reticulus-ruber* Waksman, Soil Science, 8, 1919, 146; *Actinomyces reticulus* Bergey et al., Manual, 2nd ed., 1925, 373.)

Branching filaments with both primary and secondary whirl formation. Spirals formed on dextrose agar. Conidia oval-shaped.

Gelatin stab: Surface growth yellowish-red to dragon-pink. Liquefied.

Synthetic agar: Abundant, spreading, usually pink. Aerial mycelium thin, rose to pink.

Starch agar: White with red tinge.

Dextrose agar: Extensive spreading, rose-red, entire.

Plain agar: Red, with yellowish margin, becoming red.

Dextrose broth: Thin, flaky sediment.

Litmus milk: Abundant, red pellicle; coagulated; peptonized. Reaction unchanged.

Potato: Cream-colored, later pink to dark red.

Nitrates reduced to nitrites.

Soluble dark brown, pigment formed.

Peptonization of gelatin and milk.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

58. Actinomyces flavus Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman and Curtis, Soil Science, *1*, 1916, 118.)

Coarse filaments with branching hyphae. Conidia formed by budding and breaking up of hyphae into oval forms.

Gelatin stab: Small, yellowish masses on surface of liquefied medium.

Synthetic agar: Circular, yellow or sulfur-yellow colonies. Aerial mycelium straw-yellow.

Starch agar: Spreading, cream-colored, with pink tinge.

Dextrose agar: Restricted, raised, folded, sulfur-yellow, center shading to brown.

Plain agar: Gray, spreading, folded.

Dextrose broth: Small, white colonies in bottom of tube.

Litmus milk: Coagulated; peptonized, becoming distinctly alkaline.

Potato: Elevated, much wrinkled, greenish-olive.

Traces of nitrite formed.

Soluble brown pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

59. Actinomyces ruber Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662; Waksman, Soil Science, *8*, 1919, 149.)

Straight, branching mycelium, radiating. A few spirals may be formed.

Gelatin stab: Liquefaction with yellow flakes.

Synthetic agar: Abundant, spreading, red. Aerial mycelium abundant, cottony, chrome-orange.

Starch agar: Abundant, spreading, red.

Dextrose agar: Restricted, abundant, entire, coral-red.

Plain agar: Restricted, elevated, wrinkled, olive-green.

Dextrose broth: Red ring, with spongy colonies on the surface.

Litmus milk: Dark ring with red tinge; coagulated; peptonized, with alkaline reaction.

Potato: Elevated, wrinkled, greenish.

Nitrates reduced to nitrites.

Soluble brown pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

60. **Actinomyces waksmanii** Bergey et al. (*Actinomyces violaceus* Waksman and Curtis, Soil Science, *1*, 1916, 110; *Actinomyces violaceus ruber* Waksman and Curtis, *ibid.*, 127; Bergey et al., Manual, 3rd ed., 1930, 489.)

Straight filaments with open, dextrorse spirals, breaking up into spores. Conidia oval or rod-shaped, 0.7 to 1.0 by 0.8 to 1.5 microns.

Gelatin stab: Spreading, dense, cream-colored surface growth, becoming pink or blue. Slow liquefaction.

Synthetic agar: Thin, spreading, colorless, becoming red, then blue. Aerial mycelium thin, white, powdery, becoming mouse-gray.

Starch agar: Pink, spreading.

Dextrose agar: Spreading, brick-red, almost black, entire.

Plain agar: White, becoming red with white margin.

Dextrose broth: Grayish ring.

Litmus milk: Gray ring with show of red or blue. Usually no coagulation. Peptonization, with alkaline reaction.

Potato: Small, brownish colonies, folded.

Nitrates reduced to nitrates.

Soluble blue pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

61. **Actinomyces verni** Waksman and Curtis. (Soil Science, *1*, 1916, 120.)

Filaments with close branching of the hyphae. No conidia demonstrated.

Gelatin stab: Small, cream-colored colonies. Rapid liquefaction.

Synthetic agar: Abundant, spreading, wrinkled, elevated, glossy, yellowish, becoming brownish, lichenoid margin.

Starch agar: Scant, brownish, restricted.

Dextrose agar: Abundant, much folded, center raised, gray with purplish tinge, entire.

Plain agar: Small, grayish colonies with depressed center, becoming wrinkled.

Dextrose broth: Slightly flaky sediment.

Litmus milk: Pinkish-brown ring; coagulated; peptonized, with alkaline reaction.

Potato: Cream-colored, becoming gray, wrinkled.

Nitrates reduced to nitrites.

Soluble brown pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

62. **Actinomyces albus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Straight, branching mycelium with a few short spirals. Conidia spherical or oval, 1.1 to 1.4 by 1.2 to 1.8 microns.

Gelatin stab: Small, cream-colored masses in liquefied medium.

Synthetic agar: Abundant, spreading, grayish. Aerial mycelium white, covering the surface.

Starch agar: Thin, spreading, transparent.

Dextrose agar: Thick mycelium, radiate, gray, with yellow, raised center.

Plain agar: Glossy, spreading, cream-colored.

Dextrose broth: White ring; abundant, colorless, flaky sediment.

Litmus milk: Brownish ring. No coagulation. Peptonization in 20 days.

Potato: Abundant, wrinkled, cream-colored, with greenish tinge.

Nitrates reduced to nitrites.

No soluble pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

63. **Actinomyces californicus** Waksman and Curtis. (Soil Science, *1*, 1916, 122.)

Filaments with long, narrow, open spirals. Spherical to oval conidia from straight and spiral hyphae.

Gelatin stab: Gray, moist, abundant surface growth. Liquefaction in 30 days.

Synthetic agar: Spreading, vinaceous colored. Aerial mycelium powdery, thin, light neutral gray.

Starch agar: Spreading, pink center with colorless to gray margin.

Dextrose agar: Restricted, much folded, cream-colored, with sulfur-yellow tinge.

Plain agar: Thin, restricted, yellowish to cream-colored.

Dextrose broth: Solid cream-colored mass on surface, with pink tinge.

Litmus milk: Faint, brownish surface growth; coagulated; peptonized in 40 days.

Potato: Glossy, yellow to red, turning red-brown.

Nitrates reduced to nitrites.

No soluble pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 37°C.

Habitat: Soil.

64. **Actinomyces flaveolus** Waksman. (Actinomyces 168, Waksman, Soil Science, 8, 1919, 134; Waksman in Bergey's Manual, 1st ed., 1923, 368.)

Numerous closed and open spirals on all media. Conidia oval to elliptical.

Gelatin stab: Liquefied with abundant, yellowish, spreading pellicle.

Synthetic agar: Light sulfur-yellow turning to cadmium-yellow, penetrating deep into medium. Aerial mycelium as white to ash-gray patches.

Starch agar: White, spreading.

Dextrose agar: Restricted, surface folded, raised.

Plain agar: White, glistening, wrinkled.

Dextrose broth: Thin, yellow pellicle.

Litmus milk: Sulfur-yellow ring; coagulated; peptonized, with faintly alkaline reaction.

Potato: Abundant, wrinkled, cream-colored.

Nitrates reduced to nitrites.

Soluble empire-yellow pigment formed.

Peptonization of milk and gelatin.

Starch is hydrolyzed.

Aerobic.

Optimum temperature 25°C.

Habitat: Soil.

65. **Actinomyces bobili** Waksman and Curtis. (Soil Science, 1, 1916, 121.)

Branching mycelium with branching hyphae. Few close spirals of a dextrorose type.

Gelatin stab: Dense, cream-colored to brownish surface growth. Rapid liquefaction.

Synthetic agar: Abundant, glossy, wrinkled, elevated, coral-red, becoming deep red. Scant, white, aerial mycelium.

Starch agar: Restricted, finely wrinkled, coral-red, with hyalin margin.

Plain agar: Restricted, glossy, gray, becoming brownish.

Dextrose broth: Round colonies in fluid. Flaky sediment.

Litmus milk: Dark brown ring. No coagulation. Peptonized.
Potato: Thin, yellowish, becoming red, dry, wrinkled.
Nitrates reduced to nitrites.
Soluble brown pigment formed.
Peptonization of gelatin and milk.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 37°C.
Habitat: Soil.

66. **Actinomyces roseus** Krainsky. (Cent. f. Bakt., II Abt., *41*, 1914, 662.)

Filaments with numerous open and closed spirals. Conidia 1.0 to 1.2 by 1.5 to 3.0 microns.

Gelatin stab: Liquefaction, with small, cream-colored colonies in bottom of liquid.

Synthetic agar: Thin, spreading, colorless. Aerial mycelium thin, pale, brownish.

Starch agar: Colorless, spreading.
Dextrose agar: Extensive spreading colorless, entire.
Plain agar: White, becoming yellowish.
Dextrose broth: Cream-colored ring, with flaky sediment.

Litmus milk: Brownish ring. No coagulation. Peptonized in 10 to 15 days, becoming strongly alkaline.

Potato: Much wrinkled, brownish.
Nitrates reduced to nitrites.
Purple pigment on egg media; brown on gelatin.
Peptonization of milk and gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 37°C.
Habitat: Soil.

67. **Actinomyces griseolus** Waksman. (Actinomyces 96, Waksman, Soil Science, *8*, 1919, 121; Waksman in Bergey's Manual, 1st ed., 1923, 369.)

Branching mycelium; no spirals observed. Conidia spherical or oval-shaped.

Gelatin stab: Liquefied with yellowish, flaky pellicle and sediment.

Synthetic agar: Colorless, thin, spreading, chiefly in the medium; surface growth limited almost entirely to the aerial mycelium. Aerial mycelium at first gray, later becoming pallid, neutral-gray.

Starch agar: Grayish-brown, with dark ring.

Dextrose agar: Spreading, both on the surface and into the medium; center raised, cream-colored, turning dark.

Plain agar: Brownish, with smooth surface.
Dextrose broth: Thick, brown ring.

Litmus milk: Abundant, pink pellicle; coagulated; peptonized, becoming alkaline.

Potato: Cream-colored, becoming black, spreading.
Nitrates reduced to nitrites.
Faint brownish soluble pigment formed.
Peptonization of milk and gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

68. **Actinomyces erythreus** Waksman. (Actinobacillus 161, Waksman, Soil Science, *8*, 1919, 112; Waksman in Bergey's Manual, 1st ed., 1923, 370.)

Mycelium fine, branching; numerous open spirals formed as side branches of the main hyphae.

Gelatin stab: Abundant, dense, gray with pinkish tinge, chiefly on surface of liquefied medium.

Synthetic agar: Spreading with irregular margin, developing deep into the medium; color at first white, later turning yellowish, agar around growth has a white, milky surface. Aerial mycelium, thick, solid, white.

Starch agar: Cream-colored, circular colonies, with faint greenish tinge.

Dextrose agar: Abundant, spreading, cream-colored, later turning brown chiefly on surface; center raised, lobate margin.

Plain agar: Cream-colored.

Dextrose broth: Abundant, cream-colored surface growth.

Litmus milk: Yellowish surface zone; coagulated; peptonized, becoming alkaline.

Potato: Wrinkled, cream-colored, becoming yellowish.
Nitrates reduced to nitrites.
Soluble purple pigment formed.
Proteolytic action in milk and gelatin.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 25°C.
Habitat: Soil.

69. **Actinomyces thermodiastaticus** Bergey. (Jour. Bact., *4*, 1919, 301.)

Branching mycelium and hyphae. Conidia oval.

Gelatin stab: Liquefied.

Agar colonies: Slightly spreading, colorless, fimbriate. Aerial mycelium white.

Agar slant: Restricted, colorless, turning dark.
Broth: Globular colonies in bottom of tube.
Litmus milk: Slightly acid. No coagulation. No peptonization.
Potato: Slight growth.
Nitrates show slight reduction to nitrites.
Starch is hydrolyzed.
Aerobic.
Optimum temperature 65°C.
Habitat: Isolated from stomach contents of rabbit.

70. **Actinomyces nondiastaticus** Bergey. (Jour. Bact., *4*, 1919, 301.)
Thin, branching mycelium. Conidia oval.
Gelatin stab: Liquefied.
Agar colonies: Spreading, fimbriate.
Agar slant: White, mealy surface growth.
Broth: Flocculent sediment.
Litmus milk: Acid; coagulated; peptonized.
Potato: Gray, turning dark.
Nitrates show slight reduction to nitrites.
Starch not hydrolyzed.
Aerobic.
Optimum temperature 65°C.
Habitat: Air contamination on agar plate.

Genus III. Erysipelothrix *Rosenbach, 1909.*

Rod-shaped organisms with a tendency to the formation of long filaments which may show branching. The filaments may also thicken and show characteristic granules. No spores. Non-motile. Gram-positive. Do not produce acid. Microaerophilic. Usually parasitic.

The type species is *Erysipelothrix rhusiopathiae* (Kitt) Holland.

1. **Erysipelothrix rhusiopathiae** (Kitt) Holland. (Bacillus des Schweinerotlaufs Löffler, Arbeiten a. d. Kaiserlich. Gesundheitsamte, *1*, 1886, 46; *Bacillus rhusiopathiae* Kitt, Bakterienkunde und pathologische Mikroscopie, 1893, 284; *Bacterium erysipelatis suim* Migula in Engler and Prantl, Nat. Pflanzenfamilien, *1*, *1a*, 1895, 24; *Bacterium rhusiopathiae* Migula, Syst. der Bakt., 1900, 43.)

Slender rods, ranging in size from 0.2 to 0.3 by 0.5 to 1.5 microns, occurring singly and in chains. Non-motile. Gram-positive.

Gelatin colonies: Hazy, bluish-gray, racemose; situated a little below the surface, growing slowly.

Gelatin stab: Small, fimbriate colonies in the stab, at times definitely arborescent. No surface growth. No liquefaction.

Agar slant: Scant growth, translucent, moist, homogeneous.
Broth: Slight turbidity, with scant, grayish sediment.
Litmus milk: Unchanged.
Potato: Usually no growth.
Blood serum shows scant growth.
Microaerophilic.
Optimum temperature 37°C.

Habitat: The cause of "swine erysipelas." Transmissible to gray and white mice, rabbits and pigeons. Has been transmitted to man by accidental inoculation.

2. **Erysipelothrix muriseptica** (Flügge) Bergey et al. (*Bacillus murisepticus* Flügge, Die Mikroorganismen, 1886, 250; *Pasteurella muriseptica* Bergey et al., Manual, 1st ed., 1923, 265.)

Rods: 0.5 by 0.8 to 1.0 micron, occurring singly. Non-motile. Gram-negative.

Gelatin colonies: Very small, whitish, dew-like with indefinite margin.

Gelatin stab: Filiform growth in stab, arborescent. No liquefaction.

Agar slant: Very slight, clear, dew-like streak.

Broth.

Litmus milk: Unchanged.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Microaerophilic.

Optimum temperature 37°C.

Habitat: In fatal septicemia in white mice following injection of putrid meat infusion. Not infectious for field mice.

FAMILY II. MYCOBACTERIACEAE CHESTER, 1901.

Straight or slightly curved rods, frequently irregular in form but rarely filamentous and with only slight and occasional branching. Often stain unevenly (showing variations in staining reaction within the cell). No conidia formed.

Key to the genera of family Mycobacteriaceae.

1. Non-motile.
   A. A few parasitic forms, but the greater number are saprophytic.
      a. Slender rods, acid-fast.
         Genus I. *Mycobacterium*, p. 534.
      aa. Slender rods, not acid-fast.
         Genus II. *Corynebacterium*, p. 545.
      aaa. Slender rods; parasitic.
      b. Generally Gram-positive.
         Genus III. *Fusiformis*, p. 557.
      bb. Gram-negative.
         Genus IV. *Cytophaga*, p. 558.
         Genus V. *Actinobacillus*, p. 559.
2. Motile.
   A. Soil and water bacteria. Slender rods. Gram-negative.
         Genus VI. *Mycoplana*, p. 561.
      a. Rods slightly curved. Gram-negative.
         Genus VII. *Cellvibrio*, p. 562.
         Genus VIII. *Cellfalcicula*, p. 563.

Genus I. Mycobacterium *Lehmann and Neumann, 1896.*

Slender rods which are stained with difficulty, but when once stained are acid-fast. Cells sometimes show swollen, clavate or cuneate forms, and occasionally even branched forms. Growth on media slow. Aerobic.

Several species pathogenic to animals.

The type species is *Mycobacterium tuberculosis* Schroeter Lehmann and Neumann.

Key to the species of genus Mycobacterium.

A. Parasitic in warm-blooded animals.
  1. Parasitic in man.
    1. *Mycobacterium tuberculosis* var. *hominis*.
    2. *Mycobacterium leprae*.
  2. Parasitic in bovines.
    3. *Mycobacterium tuberculosis* var. *bovis*.
    4. *Mycobacterium paratuberculosis*.
  3. Parasitic in birds.
    5. *Mycobacterium avium*.

B. Parasitic in cold-blooded animals.
  1. Parasitic in fish.
    6. *Mycobacterium piscium*.
    7. *Mycobacterium marinum*.
  2. Parasitic in frogs.
    8. *Mycobacterium ranae*.
  3. Parasitic in snakes.
    9. *Mycobacterium tropidonatum*.
    10. *Mycobacterium thamnopheos*.
  4. Parasitic in turtles.
    11. *Mycobacterium chelonei*.

C. Saprophytes.
  1. Found on skin and genitalia of man and animals.
    12. *Mycobacterium smegmatis*.
  2. Found in intestinal contents of mice.
    13. *Mycobacterium muris*.
  3. Found in butter.
    a. Litmus milk alkaline.
      14. *Mycobacterium butyricum*.
    aa. Litmus milk shows reddish-yellow ring.
      15. *Mycobacterium berolinense*.
    aaa. Litmus milk becoming dirty yellowish-brown.
      16. *Mycobacterium friburgense*.
  4. Found in manure.
    17. *Mycobacterium stercoris*.
  5. Found in hay.
    18. *Mycobacterium phlei*.
  6. Found on grain.
    19. *Mycobacterium graminis*.

7. Found in soil.

20. *Mycobacterium alluvialum.*
21. *Mycobacterium coeliacum.*

1. **Mycobacterium tuberculosis var. hominis** (Schroeter) Lehmann and Neumann. (Tuberkelbacillen, Koch, Mitteil. a.d. Kaiserlich. Gesundheitsamte, *2*, 1884, 6; *Bacillus tuberculosis* Schroeter, Cohn's Kryptogamen Flora v. Schlesien, *3*, 1886, 164; *Bacillus tuberculosis* Flügge, Die Mikroorganismen, 1886, 208; *Coccothrix tuberculosis* Lutz, Dermatol. Studien, *1*, 1886, 22; *Sclerothrix kochii* Metchnikoff, Virchow's Archiv., *113*, 1888, 70; *Mycobacterium tuberculosis* Lehmann and Neumann, Atlas und Grund. der Bakt., 1896, 363; Human tubercle bacilli, Th. Smith, Trans. Assoc. Am. Phys., *11*, 1896, 75; *Bacterium tuberculosis* Migula, in Engler and Prantl, Die natürlichen Pflanzenfamillien, I teil, Abt. *1, 1a*, 1895, 21; *Mycobacterium tuberculosis* typus *humanus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 550.)

Common name: Tubercle bacillus, human type.

Rods, ranging in size from 0.15 to 0.35 by 0.5 to 4.0 microns, occurring singly and in occasional threads. May show branching. Stain irregularly, showing banded or beaded forms. Acid-fast. Gram-positive. (Growth in all media is slow, requiring several weeks for development.)

Glycerol agar colonies: Minute, crumb-like, irregular, whitish-yellow, later brownish, ridged, moist, becoming dry.

Glycerol agar slant: Dry, crumpled, raised, yellowish, at times reddish in color.

Glycerol broth: Wrinkled, grayish pellicle.

Litmus milk.

Glycerol potato: Crumpled, yellowish to yellowish-red.

Blood serum: Flat, spreading, crumpled to rugose, yellowish-gray.

Aerobic.

Optimum temperature 37°C.

Habitat: The cause of tuberculosis in man. Transmissible to rabbits and guinea pigs.

2. **Mycobacterium leprae** (G. A. Hansen) Lehmann and Neumann. (*Bacillus leprae* G. A. Hansen, Virchow's Archiv, 1879, *79*, 1880, 32; Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 372.)

Common name: Lepra bacillus.

Rods: 0.2 to 0.35 by 1.5 to 4.6 microns, straight, rarely bent or curved. Acid-fast. Gram-positive.

Gelatin: Grayish-white, thick, granular.

Agar colonies: Grayish, circular, raised center, brownish, serrate to fimbriate margin.

Glycerol agar slant: Grayish, flat, slightly raised, becoming brownish-yellow to bright orange.

Broth: Wrinkled pellicle and thick, powdery sediment.

Litmus milk.

Glycerol potato: Slow growth, moist, raised, creamy to bright orange.
Blood serum: Slow, yellow, wrinkled growth.
Aerobic.
Optimum temperature 37°C.
Habitat: The cause of leprosy.

3. **Mycobacterium tuberculosis var. bovis** (Th. Smith) Lehmann and Neumann. (Bovine tubercle bacilli, Th. Smith, Trans. Assoc. Am. Phys., *11*, 1896, 75; *13*, 1898, 417; Jour. Exper. Med., *3*, 1898, 451; *Mycobacterium tuberculosis* typus *bovinus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 550.)

Common name: Tubercle bacillus, bovine type.

Rods which are shorter and more plump than the human type. Ranging in size from 1.0 to 1.5 microns. Very short forms are frequently intermixed with somewhat larger forms. Stain irregularly. Acid-fast. Gram-positive. (Less easily cultivated than the human variety.)

Glycerol agar: Grayish, repand.
Glycerol bouillon: Fragile pellicle slowly developed.
Glycerol milk.
Glycerol potato: Light, yellowish-gray layer.
Blood serum: Very slow development.
Egg medium: Small, flat, grayish, confluent colonies, moist, glistening.
Aerobic.
Optimum temperature 37°C.
Habitat: The cause of tuberculosis in cattle. Transmissible to man and domestic animals. More highly pathogenic for animals than the human type.

4. **Mycobacterium paratuberculosis** Bergey et al. (Darmtuberculose bacillen, Johne and Frothingham, Deutsch. Zeitsch. Tiermed., *21*, 1895, 438; Pseudotuberkulose bacillen, Bang, Berl. tierärztl, Wochensch., 1906, 759; Bacillus of Johne's Disease, McFadyen, J. Comp. Path., *20*, 1907, 48; Bergey, et al., Manual, 1st ed., 1923, 374.)

Common name: Johne's bacillus.

Slender rods, 1.0 to 2.0 microns in length, staining uniformly, but occasionally the longer forms show alternate stained and unstained segments. Non-motile. Acid-fast.

The organism is difficult to cultivate and requires special media to develop.

Habitat: The cause of Johne's disease, a chronic diarrhea in bovines. The bacteria are found in the intestinal mucosa. Not pathogenic for guinea pigs or rabbits.

5. **Mycobacterium avium** Chester. (Tuberculose des oiseuax, Strauss u. Gamaleia, Archives de Méd. exp. et d'Anat. path. 1891; Bacillus der Hühnertuberculose, Maffucci, Zeitschr. f. Hygiene, *11*, 1892, 449; *Mycobacterium tuberculosis avium* Lehmann and Neumann, Atlas u. Grund. d.

Bakt., 1896, 370; *Bacillus tuberculosis avium* Kruse, in Flügge, Die Mikro organismen, *2*, 1896, 506; *Mycobacterium avium* Chester, Manual of Determinative Bacteriology, 1901, 357; *Mycobacterium tuberculosis* typus *gallinaceus* Lehmann and Neumann, Bakt. Diag., 4 Aufl., *2*, 1907, 553.)

Common name: Tubercle bacillus, avian type.

Rods resembling those of the bovine type of tubercle organism.

Glycerol agar: Soft, flat, growing fairly rapidly.

Glycerol broth: Forms pellicle.

Glycerol milk.

Glycerol potato: Smooth, somewhat dry, repand.

Glycerol blood serum: Small, white colonies, becoming crumpled, shiny, yellowish.

Aerobic.

Optimum temperature 37°C. Good growth at 40° to 42°C.

Habitat: The cause of tuberculosis in chickens. Transmissible to pigeons, birds, mice and rabbits.

6. **Mycobacterium piscium** (Kral and Dubard) Bergey et al. (Bull. acad. de med., 1897, 580; Bataillon, Dubard and Terre, Compt. rend. de la Soc. de Biol., *4*, sér. 10, 1897, 446; Bergey et al., Manual, 1st ed., 1923, 375.)

Slender rods, occurring singly and in threads, showing branching. Acid-fast. Non-motile. Gram-positive.

Gelatin: Very slow growth, dry, wrinkled, opaque. No liquefaction.

Agar colonies: Small, circular, white, moist.

Agar slant: Scant, white, moist, cream-like.

Broth: Thin pellicle, with flocculent sediment.

Litmus milk: Thickened. No coagulation.

Potato: White, warty, butyrous colonies.

Blood serum.

Aerobic.

Optimum temperature 25°C.

Habitat: The cause of nodule and tumor-like formations in carp (*Ciprinus carpio*). Infectious for carp, frogs, lizards. Not infectious for guinea pigs and pigeons.

7. **Mycobacterium marinum** Aronson. (Jour. Infect. Dis., *39*, 1926, 315.)

In lesions, short, thick, uniformly staining organisms are seen, occurring in clumps, while long, thin, beaded or barred rods are scattered more discretely. In cultures the organisms have the same appearance. Not decolorized by 3 per cent acid alcohol or by Gabbet's solution. Non-motile. Gram-positive.

Gelatin stab: Growth slight. No liquefaction.

Dorset's and Petroff's media, at 18° to 20°C., in 14 to 18 days, show grayish-white, moist, elevated colonies with irregular margin, closely resembling those of the avian type of tubercle bacillus. Later the colonies become yellow to deep orange.

Agar slant (slightly acid): In five to seven days, moist, glistening, elevated colonies, becoming lemon yellow.

Blood agar (rabbit): No hemolysis.

Glycerol broth: Diffuse turbidity. No pellicle is formed.

Litmus milk: Acidified and coagulated.

Potato.

Indol not produced.

Nitrates not reduced.

No action on carbohydrates.

Aerobic, facultative.

Optimum temperature 18° to 20°C.

Habitat: Isolated from areas of focal necrosis of the liver of *Abudefduf mauritii*, *Micropogon undulatus* and *Centropriste striatus*. (Spontaneous tuberculosis in salt water fish.)

8. **Mycobacterium ranae** (Küster) Bergey et al. (Münch. Med. Wochenschr., 1905; Bergey et al., Manual, 1st ed., 1923, 374.)

Slender rods, acid-fast (in young cultures some of the organisms are not acid-fast) when stained in cold solutions. Non-motile. Gram-positive.

Gelatin stab: No liquefaction.

Agar colonies.

Agar slant: Dry, scaly.

Broth: Slightly turbid, with slight sediment.

Litmus milk: Becoming thin, clear. Peptonized. Yellowish, alkaline.

Potato.

Blood serum: Small, grayish-white, convex, glistening colonies.

Aerobic.

Optimum temperature 25°C.

Habitat: Isolated from the liver of frogs. Infectious for all cold-blooded animals.

9. **Mycobacterium tropidonatum** Bergey et al. (Tuberculbacillen bei Schlangen, Sibley, Virchow's Arch., *116*, 1889, 104; Tuberculbacillen bei Schlangen, Sibley, Cent. f. Bakt., *5*, 1889, 831; Trans. Path. Soc. of London, 1892; Bergey et al., Manual, 1st ed., 1923, 376.)

Rods, acid-fast. Non-motile. Gram-positive.

Gelatin stab.

Agar colonies.

Agar slant.

Broth.

Litmus milk.

Potato.

Blood serum.

Aerobic.

Optimum temperature 25°C.

Habitat: The cause of nodules and tumor-like formations in snakes (*Tropidonatus natrix*).

10. **Mycobacterium thamnopheos** Aronson. (Jour. Infect. Dis., *44*, 1929, 222.)

Slender rods: 0.5 by 4 to 7 microns, beaded and barred forms are formed. Non-motile. Gram-positive.

Dorset's egg medium colonies: Discrete, elevated, moist, soft, pinkish, becoming salmon-colored.

Gelatin stab: Slight surface growth.

Glycerol agar: Abundant growth.

Glycerol broth: Thin pellicle.

Litmus milk: Unchanged.

Potato.

Indol not formed.

Nitrates reduced.

No action on sugars.

Aerobic, facultative.

Optimum temperature 20° to 25°C.

Habitat: Isolated from garter snakes (*Thamnophis sirtalis*).

11. **Mycobacterium chelonei** Bergey et al. (Schildkröten tuberkel-bacillus Friedmann, Cent. f. Bakt., I Abt., Orig., *34*, 1903, 647; Bergey et al., Manual, 1st ed., 1923, 376.)

Common name: Turtle bacillus.

Slender rods: 0.3 by 0.5 to 4.0 microns. Not strongly acid-fast. Non-motile. Gram-positive.

Glycerol gelatin: Nodular, granular growth with radiate margin. No liquefaction.

Glycerol agar colonies.

Glycerol agar slant: At first moist, coarsely granular, yellowish-white, abundant, spreading.

Glycerol broth: Grayish-yellow, wrinkled pellicle.

Blood serum.

Aerobic.

Optimum temperature 25° to 30°C.

Habitat: Isolated from lungs of turtles in Berlin aquarium. Infectious for cold-blooded animals, but not for warm-blooded animals, except guinea pigs.

12. **Mycobacterium smegmatis** Lehmann and Neumann. (Smegma bacillus, Alverez and Tavel, Arch. de Physiol. norm. et path., 1885; *Bacillus smegmatis* Kruse in Flügge, Die Mikroorganismen, *2*, 1896, 517; *Bacterium smegmatis* Migula, System der Bakterien, 1900, 497; Lehmann and Neumann, Atlas u. Grund. d. Bakt., 4 Aufl., 1907, 560.)

Common name: Smegma bacillus.

Rods, usually more plump than *Mycobacterium tuberculosis*, variable in size. Not as highly acid-fast as the tubercle bacteria. Gram-positive.

Gelatin stab: Slow and scant development. No liquefaction.

Agar colonies: Minute, grayish-white, dry, circular.

Glycerin agar slant: Occurs as isolated colonies, becoming lobulated and velvety, grayish, butyrous.

Broth: Dry, white pellicle.

Litmus milk: Litmus reduced. Slow coagulation.

Potato: Luxuriant, dull, yellow.

Blood serum: Fairly thick, grayish-yellow layer.

Aerobic.

Optimum temperature 30° to 35°C.

Habitat: Found on the genitalia, especially in smegma. Not pathogenic.

13. **Mycobacterium muris** Simmons. (Jour. Infect. Dis., *41*, 1927, 13.)

Acid fast rods: 0.5 to 0.5 by 1.5 to 4.0 microns. Many cells are banded or beaded, sometimes with slightly swollen ends. Occur singly and occasionally in pairs. Gram-positive.

Colonies on Petroff's medium: Small, flat, irregular, dry, grayish-white, becoming wrinkled and nodular.

Colonies on glycerine agar: Small, grayish-white, irregular, dry, scaly, becoming wrinkled and nodular. Older cultures show light yellowish tan color.

Colonies on blood serum: Small, white, dry, scaly, becoming raised and nodular.

Glycerol broth: Slight granular growth near the surface after two weeks.

Glycerol potato: Dry, wrinkled, granular, grayish tan in color.

No action on carbohydrates.

Anaerobic.

Optimum temperature 37°C.

Non-pathogenic.

Habitat: Intestinal contents of wild gray mice.

14. **Mycobacterium butyricum** (Petri) Bergey et al. (Arbeiten a. d. Kaiserlich. Gesundheitsamte, 1897; Bergey et al., Manual, 1st ed., 1923, 377.)

Rods like *Mycobacterium tuberculosis.*

Gelatin stab: Grow slowly as isolated colonies in stab. No liquefaction.

Agar colonies: Circular, gray, granular, crumpled.

Agar slant: Thick, moist, becoming orange, crumpled.

Broth: Crumpled pellicle.

Litmus milk: Alkaline.

Potato: Moist, gray.

Blood serum.

Indol is formed.

Aerobic.

Optimum temperature 25°C.

Habitat: Isolated from butter.

15. **Mycobacterium berolinense** Bergey et al. (Tuberkelähnlichen Bacillen, Rabinowitsch, Zeitschr. f. Hyg., *26*, 1897, 90; Bergey et al., Manual, 1st ed., 1923, 377.)

Rods like *Mycobacterium tuberculosis*, but often clubbed, occurring singly and lying parallel, at times forming long, ramified filaments. Acid-fast. Gram-positive.

Gelatin colonies: Small, granular, transparent.

Gelatin stab: Slow growth. No liquefaction.

Agar colonies: Golden or copper-colored, wrinkled, moist, thick, creamy, glistening.

Agar slant: Golden, wrinkled, thick, moist, creamy.

Broth: Turbid. Thick, wrinkled pellicle. Disagreeable, ammoniacal odor.

Litmus milk: Reddish-yellow ring. No coagulation.

Potato: Whitish to orange, raised, dull, dry, wrinkled.

Blood serum.

Trace of indol formed.

H_2S is formed.

Aerobic.

Optimum temperature 37°C.

Habitat: Isolated from butter in Berlin and in Philadelphia.

16. **Mycobacterium friburgense** (Korn) Bergey et al. (*Bacillus friburgensis* Korn, Cent. f. Bakt., I Abt., *25*, 1899, 532; Bergey, et al., Manual, 1st ed., 1923, 378.)

Rods more plump than *Mycobacterium tuberculosis* ranging from coccoid forms to definite rods with rounded ends, at times exhibiting branching. Acid-fast. Non-motile. Gram-positive.

Gelatin colonies: Circular, flat, white, lobate.

Gelatin stab: Abundant, creamy-white, smooth surface growth. No liquefaction.

Agar colonies: Circular, grayish-white.

Glycerin agar slant: Thick, rough, glistening, crumpled, yellowish-white, becoming yellowish-brown.

Broth: Yellowish pellicle and sediment.

Litmus milk: Becoming dirty, yellowish-brown. No coagulation.

Potato: Soft, flat, whitish, becoming brownish.

Blood serum.

Aerobic.

Optimum temperature 37°C.

Habitat: Isolated from butter in Freiburg.

17. **Mycobacterium stercoris** Bergey et al. (Mist bacillus, Moeller, Berlin. thierartzl. Wochenschr., 1898, 100; Bergey et al., Manual, 1st ed., 1923, 378.)

Rods: 0.2 to 0.4 by 1.0 to 4.0 microns, may show threads. Non-motile. Acid-fast. Gram-positive.

Gelatin colonies.

Gelatin stab: Very slight surface growth. Best growth in stab. No liquefaction.

Agar colonies: Raised, gray-white.

Agar slant: Grayish-white, becoming chamois color.

Broth: Turbid, with yellowish ring and sediment.

Litmus milk: Acid. Sometimes coagulated. Yellowish-red pellicle.

Potato.

Blood serum.

Aerobic.

Optimum temperature 37°C.

Habitat: Isolated from cow manure.

18. **Mycobacterium phlei** Bergey et al. (Timothy hay bacillus, Moeller, Therapeutischen Monatscheften, 1898; Moeller, Deut. Med. Wochenschr. *24*, 1898, 376; Bergey et al., Manual, 1st ed., 1923, 378.)

Slender, beaded rods, 0.2 to 0.5 by 1.4 microns, sometimes club-shaped. Acid-fast. Non-motile. Gram-positive.

Gelatin colonies: Small.

Gelatin stab: Poor growth. No liquefaction.

Agar colonies: Yellow-white, wrinkled.

Agar slant: Abundant, yellow, wrinkled.

Broth: Turbid, with yellow pellicle.

Litmus milk: Yellow flocculi on surface. No coagulation.

Potato: Thick, dry, yellow, adherent.

Blood serum.

Aerobic.

Optimum temperature 37°C.

Habitat: Isolated from timothy grass, dust and milk.

19. **Mycobacterium graminis** Bergey et al. (Grasbacillus II, Moeller, Cent. f. Bakt., I Abt., *25*, 1899, 369; Bergey et al., Manual, 1st ed., 1923, 379.)

Rods: 0.2 to 0.4 by 1.5 microns, showing branching threads in old cultures. Acid-fast. Non-motile. Gram-positive.

Gelatin colonies.

Gelatin stab: Thick, grayish-white growth along stab. No liquefaction.

Agar colonies.

Glycerin agar slant: Delicate, moist, spreading, raised, yellowish.

Broth: Grayish-white pellicle with ropy sediment.

Litmus milk: Acid.

Potato: Thick, grayish-white.

Blood serum.

Aerobic.

Optimum temperature 37°C.

Habitat: Isolated from plant dust.

20. **Mycobacterium alluvialum** Bergey et al. (Kersten, Cent. f. Bakt., I Abt., Orig., *51*, 1909, 494; Bergey et al., Manual, 1st ed., 1923, 379.)

Slender rods, sometimes slightly swollen at one end, straight or slightly curved. They stain irregularly, showing banded or beaded structure. Acid-fast. Non-motile. Gram-positive.

Gelatin colonies: Circular, glistening, yellow.

Gelatin stab: Dirty-white, glistening surface growth, becoming yellowish brown. No liquefaction.

Agar slant: Dirty-white, granular, later concentrically ringed, yellowish-brown.

Broth: Turbid, becoming clear, with yellowish-red sediment.

Litmus milk.

Glycerin potato: Thick, folded, granular, dirty-white.

Blood serum: Abundant growth.

Indol is formed.

H_2S is formed.

Gas is formed in carbohydrate media.

Aerobic.

Optimum temperature 25° to 30°C.

Habitat: Isolated from soil. Not pathogenic.

21. **Mycobacterium coeliacum** Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 74; *Flavobacterium coeliacum* Bergey et al., Manual, 3rd ed., 1930, 156.)

Short, curved, uneven-sided rods 0.8 by 5.0 microns. Gram-positive. Young cultures show slight degree of acid-fastness. In milk cultures fairly acid-fast coccoid forms are developed.

Gelatin colonies: Irregular, white, raised, rugose, undulate.

Gelatin stab: No liquefaction. Surface growth, buff-white to yellowish, lobate margin.

Agar colonies: Small, circular, smooth, white, raised, undulate, becoming pale pinkish-buff in color.

Agar slant: Filiform, white, rugose, undulate.

Broth: Turbid.

Litmus milk.

Potato.

Indol.

Nitrates not reduced.

Starch not hydrolyzed.

Attacks phenol.

Aerobic.

Optimum temperature 30°C.

Habitat: Soil.

Genus II. **Corynebacterium** *Lehmann and Neumann, 1896.*

Slender, often slightly curved, rods with a tendency to club and pointed forms, with branching forms in old cultures. Barred, uneven staining. Not acid-fast. Gram-positive. Non-motile. Aerobic. No endospores Some pathogenic species produce a powerful exotoxin. Characteristic snapping motion is exhibited when cells divide.

The type species is *Corynebacterium diphtheriae* (Flügge) Lehmann and Neumann.

Key to the species of genus **Corynebacterium.**

I. True diphtheria organism.
  Slender rods, curved or straight, of variable length; granular or segmented; generally club-shaped. Metachromatic granules are large.
    1. *Corynebacterium diphtheriae.*

II. The "diphtheroid" group of bacteria.
  A. Small, thick rods, showing solid, barred and wedge-shaped forms. Metachromatic granules are small. Produce a heavy, confluent, glistening growth on blood serum, yellow to salmon pink in color. Ferment dextrose and sucrose. Some strains also ferment maltose.
    1. Pigment salmon-pink.
      2. *Corynebacterium hoagii.*
    2. Pale yellow, or non-pigment producing. Ferment dextrin and glycerol.
      a. Pathogenic for animals.
        3. *Corynebacterium enzymicum.*
        4. *Corynebacterium pyogenes.*
      b. Not pathogenic.
        5. *Corynebacterium hodgkinii.*
        6. *Corynebacterium segmentosum.*
  B. Large, thick, barred or beaded rods with club-shaped ends. Metachromatic granules are large. Growth on blood serum is heavy and varies from white to yellow, moist to dry and granular. Dextrose is fermented; maltose and glycerol are usually fermented; sucrose is not fermented.
    7. *Corynebacterium flavidum.*
    8. *Corynebacterium ulcerogenes.*
    9. *Corynebacterium periplanetae.*
    10. *Corynebacterium blattellae.*
  C. Medium-sized rods showing solid and barred forms. Metachromatic granules are small. Growth on blood serum slow, scanty, colorless or white. Ferment dextrose and usually both maltose and sucrose.
    11. *Corynebacterium xerosis.*

D. Small, thick, straight rods, often barred and wedge-shaped, showing no granules. Growth on serum scanty or abundant, white or yellow-white. Do not ferment dextrose, maltose, sucrose or glycerol.

12. *Corynebacterium pseudiphtheriticum.*

E. Small, thick rods, straight, barred and wedge-shaped. Growth on serum scant. Ferment dextrose. Microaerophilic to anaerobic.

13. *Corynebacterium acnes.*
14. *Corynebacterium lymphophilum.*

F. Short, thick rods, straight, barred and occasionally club-shaped. Occur in animals.

a. Occur in rabbits and guinea pigs.

15. *Corynebacterium pseudotuberculosis.*

b. Occur in mice.

16. *Corynebacterium kutscheri.*
17. *Corynebacterium murisepticum.*

c. Occur in birds and fowl.

18. *Corynebacterium cuculi.*
19. *Corynebacterium gallinarum.*

d. Occur in sheep.

20. *Corynebacterium ovis.*

e. Occur in bovines.

21. *Corynebacterium bovis.*

G. Long thin rods.

22. *Corynebacterium renale.*

1. **Corynebacterium diphtheriae** (Flügge) Lehmann and Neumann. (Klebs, Verhandlungen des Congress. f. innere med., 1883; die Klebs'schen Stäbchen, Löffler, Mitteil. a. d. Kaiserl. Gesundheitsamte, 1884; *Bacillus diphtheriae* Flügge, Die Mikroorganismen, 1886, 225; Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1896, 350; *Bacterium diphtheriae* Migula, System der Bakterien, 1900, 499.)

Common name: Diphtheria bacillus.

Rods, varying greatly in dimensions, 0.3 to 0.8 by 1.0 to 8.0 microns, occurring singly. The rods are straight or slightly curved, frequently swollen at one or both ends. The rods do not, as a rule, stain uniformly but show alternate bands of stained and unstained material. In older cultures and by special methods of staining, the bands appear as granules—metachromatic granules. Non-motile. Gram-positive.

Gelatin colonies: Slow development. Very small, grayish, lobulate.

Gelatin stab: Slight growth on surface and scant growth in stab. No liquefaction.

Agar colonies: Small, grayish, granular, almost transparent, lace-like. margin irregular.

Agar slant: Scant, grayish, granular, translucent, with irregular margin.

Broth: Fine, granular deposit on sides and bottom of tube, forming a thin, fragile pellicle on neutral medium.

Litmus milk: Unchanged.

Potato: No visible growth.

Blood serum: Grayish to creamy, moist, smooth, slightly raised, margin entire.

Indol is not formed.

Nitrates are not reduced.

All strains form acid in dextrose and levulose, some strains also ferment galactose, maltose, dextrin and glycerol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: The cause of diphtheria in man. Transmissible to guinea pigs, kittens and rabbits.

A highly poisonous exotoxin is produced in fluid media. This toxin represents the principal disease producing agency of the organism.

A highly potent antitoxin can be produced by repeated injection of toxin into experimental animals. The antitoxin possesses both curative and protective properties.

By immunizing rabbits through injection of the dead organisms a potent agglutinating serum is produced. With the aid of such serums the diphtheria organisms can be separated into five distinct groups.

The five serological types of the diphtheria organism possess the following fermenting powers, according to Durand (W. H. Park, A. W. Williams and A. G. Mann, Jour. of Immunology, 7, 1922, 243).

	Maltose	*Dextrin*	*Glycerol*	*Galactose*	*Sucrose*
Type I—American (No. 8).........	+	+	–	–	–
Type II—Durand.................	–	–	–	–	–
Type III—Nodet..................	+	+	+	+	–
Type IV—Benjamin...............	+	+	+	+	–
Type V—Sirbeaux................	+	+	+	+	–

2. **Corynebacterium hoagii** (Morse) Bergey et al. (Bacillus X, Hoag, Boston Med. & Surg. Jour., *157*, 1907, 10; *Bacillus hoagii* Morse, Jour. of Infect. Dis., *11*, 1912, 284; Bergey et al., Manual, 1st ed., 1923, 382.)

Rods: 0.8 to 1.0 by 1.0 to 3.0 microns, occurring singly. Show polar staining in the shorter forms while the longer forms are barred and slightly club-shaped. Non-motile. Gram-positive.

Gelatin colonies: Small, dull, pale pink, entire.

Gelatin stab: Slight pink surface growth. No liquefaction.

Agar colonies: Small, pale pink, dull, granular, entire.

Agar slant: Filiform, dull, pink.

Broth: Turbid, with slight pink sediment.

Litmus milk: Slightly alkaline, with pink sediment.

Potato: Dull, filiform streak.
Indol not formed.
Nitrates not reduced.
Blood serum: Dull, filiform, pink streak.
Aerobic.
Optimum temperature 30°C.
Habitat: Air contamination of cultures.

3. **Corynebacterium enzymicum** (Mellon) Bergey et al. (*Bacillus enzymicus* Mellon, The Med. Record, 89, 1916, 240; Jour. of Bact., *2*, 1917, 297; Bergey et al., Manual, 1st ed., 1923, 382.)

Rods, beaded and club-shaped, very definitely pleomorphic, showing coccoid forms. Non-motile. Gram-positive.

Gelatin stab: Slight surface growth. No liquefaction.

Dextrose agar: Bacillary form shows very small colorless colonies. Coccoid form shows heavy, yellowish-white, moist growth.

Blood agar: Same as on dextrose agar.

Löffler's blood serum: Fine, moist, confluent.

Dextrose broth: Bacillary form shows granular sediment. Coccoid form shows diffuse, luxuriant growth.

Litmus milk: Acid; coagulated.
Potato: No growth.
Indol formation slight.
Slight reduction of nitrates to nitrites.
Acid in dextrose, maltose, sucrose, dextrin and glycerol.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Lungs, blood and joints of humans. Pathogenic for rabbits, guinea pigs and mice.

4. **Corynebacterium pyogenes** (Glage) Brown and Orcutt. (*Bacillus liquefaciens pyogenes bovis* Lucet, Ann. Inst. Pasteur, *7*, 1893, 327; not *Bacillus pyogenes bovis* Lucet, not *Bacillus pyogenes* Lucet, *idem*; Bakterium der multipler Abszessbildung der Schweine, Grips, Zeitschr. f. Fleisch- u. Milchhyg., *8*, 1898, 166; *Bacillus pyogenes* Glage, Zeitschr. f. Fleisch- u. Milchhyg. *13*, 1903, 166; *Bacterium hypopyogenes* Lehmann and Neumann, Bakt., Diagnostik, 5 Aufl., *2*, 1912, 432; *Bacterium pyogenes suis* Lehmann and Neumann, Bakt. Diag., 7 Aufl., *2*, 1927, 499; *Bacterium pyogenes* Ward, Jour. Bact., *2*, 1917, 619; Brown and Orcutt, Jour. Exp. Med., *32*, 1920, 244.)

Rods: 0.2 by 0.3 to 2 microns in length. Smallest forms appear as scarcely visible points. Common in old abscesses. Chains formed. Club forms may be present. Gram positive, non-motile.

No growth on ordinary agar.

Serum agar: Grows on serum agar. Minute colonies after 36 to 48 hours. Surface colonies may increase to 3 mm. in diameter. Colonies smoky brown by transmitted light and bluish white by reflected light.

Bovine blood serum slants: Pit like or more general areas of liquefaction.

Serum bouillon: Cloudy with fine flocculent grayish flakes that form a sediment like a streptococcus culture.

Milk: Slight coagulation after 48 hrs. at 37°C. with acid at bottom of tube becoming complete in 3 days with separation of whey and peptonization.

Acid formed in serum bouillon from dextrose, saccharose, lactose, and xylose but not from raffinose, inulin, mannitol and salicin.

Beta hemolytic, not hemoglobinophilic though growth is favored by proteins and as egg albumen, serum or blood.

Optimum temperature 37°C., growth range 20 to 40°C.

Intravenous injection of rabbits fatal.

Habitat: Found in abscesses in cattle, swine and other domestic animals.

5. **Corynebacterium hodgkinii** (Bunting and Yates) Bergey et al. (Johns Hopkins Hosp. Bull., *25*, 1914, 173; Bergey et al., Manual, 1st ed., 1923, 383.)

Rods, banded or beaded, short, thick and wedge-shaped. Gram-positive.

Gelatin stab: Very slight growth. No liquefaction.

Dextrose agar: No growth.

Blood agar: Scant, moist, yellowish-red growth.

Löffler's blood serum: As on blood agar.

Dextrose broth: Slightly turbid, with nebulous sediment.

Litmus milk: Acid; coagulated on boiling.

Potato: No growth.

Indol not formed.

Slight reduction of nitrates to nitrites.

Acid in dextrose, maltose, sucrose, dextrin and glycerol.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Lymph glands in Hodgkin's disease. Not pathogenic.

6. **Corynebacterium segmentosum** (Cautley) Bergey et al. (Rept. Med. Officer of Health, Local Govt. Board, London, 1894–95, 455; Bergey et al., Manual, 1st ed., 1923, 383.)

Rods of variable dimensions, mostly resembling *Corynebacterium pseudodiphtheriticum*, but occasionally resembling *Corynebacterium diphtheriae* as long segmented forms. Non-motile. Gram-positive.

Gelatin colonies: Small, circular, white to cream-color.

Gelatin stab: Slight surface growth. No liquefaction.

Agar colonies: Circular, white to cream-color, smooth, raised, transparent, undulate.

Agar slant: Creamy-white, smooth, slightly raised.

Löffler's blood serum: Grows like *Corynebacterium diphtheriae.*

Broth: Clear, with slight, filmy sediment.

Litmus milk: Slightly acid. No coagulation.

Potato: Thin, whitish, barely visible.

Indol not formed.

Nitrates not reduced.
Acid in dextrose, maltose and sometimes also in sucrose.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Nasal secretions. Not pathogenic.

7. **Corynebacterium flavidum** (Morse) Bergey et al. (*Bacillus flavidus* Morse, Jour. of Infect. Dis., *11*, 1912, 284; Bergey et al., Manual, 1st ed., 1923, 384.)

Rods: 0.75 to 1.0 by 3.0 to 5.0 microns, barred and club-shaped. Vary considerably in size and shape. Non-motile. Gram-positive.
Gelatin stab: Slight surface growth. No liquefaction.
Dextrose agar: Yellowish, spreading, adherent, wrinkled or corrugated radially. May show slight hemolysis.
Löffler's blood serum: Yellowish-white to yellow.
Dextrose broth: Often forms thin pellicle.
Litmus milk: Slightly acid, becoming slightly alkaline.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Acid in dextrose, maltose and glycerol.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Nose and throat. Similar organisms have been found in the udder of cows with mammitis. Frequently pathogenic for laboratory animals.

8. **Corynebacterium ulcerogenes** *comb. nov.* (*Corynebacterium diphtheriae ulcerogenes cutaneum* Mrongovius, Cent. f. Bakt., I Abt., Orig., *112*, 1929, 51.)

Rods: Short, staining irregularly, with rounded ends, becoming club-shaped. Non-motile. Gram positive.
Gelatin stab: No liquefaction.
Agar colonies: Small, glistening, gray, entire.
Agar slant: Broad, thin, gray streak, entire.
Broth: Turbid with flocculent sediment.
Litmus milk: Unchanged.
Potato: Very slight growth.
Indol is not formed.
Acid formed in dextrose, levulose and sucrose. No action on galactose, lactose or maltose.
Aerobic.
Optimum temperature 37°C.
Habitat: Ulcerations of the skin in a man. Non-pathogenic for other men, for guinea pigs or mice.

9. **Corynebacterium periplanetae** Glaser (*Corynebacterium periplanetae* var. *americana* Glaser, Jour. Exp. Med., *51*, 1930, 98.)

Rods: 0.4 to 1.0 by 1.6 to 4.8 microns, occurring singly, with club-shaped ends. The rods are straight or slightly curved, showing bands or bipolar staining. Non-motile, Gram-positive.

Gelatin stab: No liquefaction.

Dextrose agar colonies. Circular, minute, gray.

Agar slants: Minute, clear, circular colonies.

Broth (serum): Moderate turbidity.

Litmus milk: Slight acidity after one month.

Potato: No growth.

Indol is not formed.

Nitrates are not reduced.

Acid in dextrose, maltose and sucrose. No action on lactose or mannitol.

Aerobic.

Optimum temperature 30–36°C.

Habitat: Occur in the fat tissue of the American Cockroach (*Periplaneta Americana*).

10. **Corynebacterium blattellae** Glaser. (Jour. Exp. Med., *51*, 1930, 907.)

Pleomorphic rods, 0.4 to 0.8 by 0.8 to 4.8 microns. Non-motile, Gram-positive.

Gelatin stab:

Dextrose, horse-blood agar colonies: Very small, pale.

Acid formed in dextrose, maltose and sucrose.

Habitat: Found in fat tissue of the German cockroach (*Blatella germanica*).

11. **Corynebacterium xerose** (Neisser and Kuschbert) Lehmann and Neumann. (*Bacillus xerosis* Neisser and Kuschbert, Deutsche med. Wochenschr., 1884; Lehmann and Neumann, Atlas u. Grund. der Bakt., 2 Aufl., 1899, Eng. ed. 1901, 406.)

Common name: Xerosis bacillus.

Rods, showing polar staining, occasionally club-shaped forms are seen. Non-motile. Gram-positive.

Gelatin colonies: Rarely develop.

Gelatin stab: Usually no growth.

Agar colonies: Minute, circular, almost transparent, raised, smooth.

Agar slant: Thin, grayish, limited.

Löffler's blood serum: Thin, grayish, adherent.

Broth: Clear, with slight, granular sediment.

Litmus milk: Unchanged.

Potato: No visible growth.

Indol not formed.

Nitrates not reduced.

Acid formed in dextrose, levulose, galactose, maltose and sucrose.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from normal and diseased conjunctiva.

Not pathogenic.

12. **Corynebacterium pseudodiphthericum** Lehmann and Neumann. (Bacillus der pseudodiphtherie, Loeffler, Cent. f. Bakt., *2*, 1887, 105; G. v. Hoffmann, Wien. Med. Wochenschr., 1888, 30; Lehmann and Neumann, Atlas u. Grund. d. Bakt., *2*, 1896, 361; *Bacillus pseudodiphthericus* Kruse in Flügge, Die Mikroorganismen, *2*, 1896, 476; *Bacterium pseudodiphthericum* Migula, System der Bakterien, 1900, 355; *Mycobacterium pseudodiphthericum* Chester, Manual of Determinative Bacteriology, 1901, 355; *Corynebacterium hoffmannii*, Bergey et al., Manual, 1st ed., 1923, 385.)

Rods, with rounded ends, 0.3 to 0.5 by 0.8 to 1.5 microns, fairly uniform in size, without swollen ends. Barred forms occur, though mostly polar-staining forms are seen. Non-motile. Gram-positive.

Gelatin colonies: Small, grayish to cream-colored, smooth, homogeneous, entire.

Gelatin stab: Slight surface growth. No liquefaction.

Agar colonies: Opaque, grayish to cream-colored, smooth, homogeneous, entire.

Agar slant: Moist, smooth, cream-colored, entire.

Löffler's blood serum: Like on agar.

Broth: Slightly turbid with slight, grayish, sediment.

Litmus milk: Unchanged.

Potato: Slight, creamy-white, smooth, entire.

Indol not formed.

Nitrates reduced to nitrites.

No acid formed in carbohydrate media.

Aerobic, facultative.

Optimum temperature 37°C.

Not pathogenic.

Common name: Pseudodiphtheria bacillus.

Habitat: Frequently found in normal throats.

13. **Corynebacterium acnes** (Gilchrist) Bergey et al. (Johns Hopkins Hosp. Repts., *9*, 1901, 409; Bergey et al., Manual, 1st ed., 1923, 385.)

Rods, vary in dimensions, usually 0.5 by 0.5 to 2.0 microns, sometimes slightly club-shaped. Show alternate bands of stained and unstained material. Non-motile. Gram-positive.

Growth in culture media very feeble.

Best growth occurs in shake cultures with soft, slightly acid, dextrose agar.

Agar slant: Very small, circular transparent colonies, later rose-colored.

Löffler's blood serum: Small, grayish colonies, becoming rose-colored.

Broth: Clear.

Litmus milk: Soft coagulum.

Potato: No growth in aerobic cultures, but pink streak in anaerobic cultures.

Indol not formed.

Nitrates not reduced.

Slight acid formation in dextrose.
Microaerophilic.
Optimum temperature 35° to 37°C.
Not pathogenic.
Common name: Acne bacillus.
Habitat: Isolated from sweat glands, hair follicles and from acne pustules.

14. **Corynebacterium lymphophilum** (Torrey) Bergey et al. (*Bacillus lymphophilus* Torrey, Jour. of Med. Research, *34*, 1916, 79; Bergey et al., Manual, 1st ed., 1923, 386.)

Rods: 0.4 to 0.5 by 1.0 to 3.2 microns, staining irregularly and occasionally showing slightly club-shaped forms. Gram-positive.
Growth occurs in media containing fresh, sterile tissue.
Gelatin stab: No growth.
Löffler's blood serum: Raised, white growth.
Broth: Turbid, with heavy sediment.
Litmus milk: Unchanged.
Potato: No growth.
Indol is not formed.
Nitrates not reduced.
Acid formed in dextrose and glycerol.
Anaerobic.
Optimum temperature 37°C.
Habitat: Isolated from lymph glands in Hodgkins disease, but is not specific for the disease. Not pathogenic.

15. **Corynebacterium pseudotuberculosis** (Eisenberg) Bergey et al. (Bacillus der pseudotuberculose, Pfeiffer, Ueber die bacilläre Pseudotuberculose bei Nagetieren, Leipzig, 1889; *Bacillus pseudotuberculosis* Eisenberg, Bakt. Diag., 1891, 294; *Streptobacillus pseudotuberculosis rodentium* Preisz, Ann. de l'Institut Pasteur, *8*, 1894, 231; *Bacterium pseudotuberculosis rodentium* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1 Aufl., *2*, 1896, 362; *Bacterium pseudotuberculosis* Migula, System der Bakterien, 1900, 374; *Corynebacterium rodentium* Bergey et al., Manual, 1st ed., 1923, 386; Bergey et al., Manual, 2nd ed., 1925, 394.)

Short, plump rods, 1.0 to 2.0 microns in length, occurring often as coccoid forms. Non-motile. Gram-negative.
Gelatin colonies: Circular, transparent, becoming darker, with concentric rings, entire, becoming irregular.
Gelatin stab: Thick slimy surface growth. No liquefaction.
Agar colonies: Circular, convex, homogeneous, grayish-white, soft, slimy.
Agar slant: Raised, grayish, slimy, viscid streak.
Broth (alkaline): Slight ring formation with thin pellicle and slight sediment.
Litmus milk: Unchanged.

Potato: Yellowish-brown streak.
Löffler's blood serum: Clear, transparent colonies.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 30° to 35°C.
Habitat: The cause of spontaneous disease in rabbits and guinea pigs. Infectious for mice, rats, dogs, cats and horses.

16. **Corynebacterium kutscheri** (Migula) Bergey et al. (*Bacillus pseudotuberculosis murium* Kutscher, Zeitschr. f. Hyg., *18*, 1894, 338; *Bacillus pseudotuberculosis murium* Lehmann and Neumann, 1 Aufl., *2*, 1896, 362; *Bacterium kutscheri* Migula, Syst. Bakt. 1900, 372; *Mycobacterium pseudotuberculosis* Chester, Determ. Bact., 1901, 355; *Corynebacterium murium* Bergey et al., Manual, 1st ed., 1923, 386; Bergey et al., Manual, 2nd ed., 1925, 395.)
Rods with pointed ends, staining irregularly. Gram-positive.
Gelatin colonies: Small, white, translucent.
Gelatin stab: No growth on surface. White, filiform growth in stab. No liquefaction.
Agar colonies: Small, thin, yellowish-white, translucent, serrate.
Agar slant: Thin, white, translucent.
Löffler's blood serum: Abundant growth.
Broth: Slight turbidity. Crystals of ammonium magnesium phosphate are formed.
Litmus milk: Unchanged.
Potato: No growth.
Indol not formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Isolated from cheesy mass in lung of mouse.

17. **Corynebacterium murisepticum** v. Holzhausen. (Cent. f. Bakt., I Abt., Orig., *105*, 1927–28, 94.)
Rods, narrow, 1.2 to 1.5 microns in length, with polar granules. Grow out into long filaments. Non-motile. Gram-positive.
Gelatin stab: Feeble growth, with fimbriate outgrowth along line of puncture.
Egg glycerol broth: Good growth.
Loeffler's blood serum: Shows good growth.
Broth: Turbid.
Litmus milk: Acid. No coagulation.
Potato: Shows good growth.
Indol not formed.
Nitrates not reported.
Acid in dextrose, levulose, galactose, maltose, lactose, sucrose, inulin and mannitol. Arabinose and isodulcitol are not attacked.

H_2S formed.
Pathogenic for mice.
Aerobic, facultative.
Optimum temperature 37°C.
Habitat: Septicemia in mice.

18. **Corynebacterium cuculi** (Graham-Smith) Bergey et al. (*Bacillus cuculi* Graham-Smith, Jour. of Hyg., *4*, 1904, 315; Bergey et al., Manual, 1st ed., 1923, 387.)

Rods of variable dimensions, curved, clubbed, solid or with light band in center. Non-motile. Gram-positive.
Gelatin colonies: No growth.
Gelatin stab: No growth.
Agar colonies: Circular, convex, white, smooth, entire.
Agar slant: White, raised, smooth.
Broth: Slightly turbid, with finely granular sediment.
Litmus milk.
Potato: No visible growth.
Löffler's blood serum: Creamy-white, smooth, soft.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 35° to 37°C.
Habitat: Isolated from throat of cuckoo. Not pathogenic.

19. **Corynebacterium gallinarum** Bergey et al. (*Bacillus diphtheroides gallinarum* Graham-Smith, Jour. of Hyg., *4*, 1904, 314; Bergey et al., Manual, 1st ed., 1923, 387.)

Rods, long, curved, clubbed and segmented. Gram-positive.
Gelatin colonies: Minute, circular, transparent.
Gelatin stab: Very little surface growth. No liquefaction.
Agar colonies: Small, filmy, transparent, gray.
Agar slant: Almost transparent film.
Löffler's blood serum: Cream-colored, margin becoming crenated.
Broth: Clear, with slight, granular sediment.
Litmus milk.
Potato.
Indol is formed.
Nitrates not reduced.
Aerobic, facultative.
Optimum temperature 35° to 37°C.
Not pathogenic.
Habitat: Isolated from throat of chicken.

20. **Corynebacterium ovis** Bergey et al. (Nocard, Bull. de la Soc. Centr. de med. Vet., 1885, 207; Preisz, Cent. f. Bakt., *10*, 1891, 568; *Bacillus pseudotuberculosis ovis* Lehmann and Neumann, Atlas u. Grund. d. Bakt., 1 Aufl., *2*, 1896, 362; Bergey et al., Manual, 1st ed., 1923, 388.)

Slender rods: 0.5 to 0.6 by 1.0 to 3.0 microns, staining irregularly and showing clubbed forms. Non-motile. Gram-positive.

Gelatin colonies: Slight development.

Gelatin stab: No liquefaction.

Agar colonies: Thin, grayish-white, folded, serrate.

Agar slant.

Löffler's blood serum: Small, yellow, serrate colonies.

Broth: No turbidity. Granular sediment.

Litmus milk.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

Pathogenic. Forms exotoxin.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from kidney of sheep.

21. **Corynebacterium bovis** Bergey et al. (Manual, 1st ed., 1923, 388.)

Rods, slender, barred, clubbed, 0.5 to 0.7 by 2.5 to 3.0 microns. Non-motile. Gram-positive.

Gelatin stab: Slight gray, flat surface growth.

Agar colonies: Circular, gray, slightly raised, radiate, undulate, dry.

Agar slant: Thin, gray, filiform, dry.

Broth: Slight granular sediment.

Litmus milk: Slowly becoming deeply alkaline.

Potato: No growth.

Indol not formed.

Nitrates not reduced.

No acid in carbohydrate media.

Blood serum: Thin, gray, filiform.

Aerobic.

Optimum temperature 37°C.

Habitat: Causative agent of polynephritis in cattle.

22. **Corynebacterium renale** Ernst. (*Bacillus pyelonephritis bovis* Enderlen, Zeit. f. Tiermed. *17*, 1890, 325; Ernst, Cent. f. Bakt., 1 Abt., Orig., *40*, 1905, 79; *Bacillus renalis*, Ernst, *ibid.*, 81; *Bacillus renalis bovis* Ernst, *ibid.*, 82; See Jones and Little, Jour. Exp. Med., *44*, 1926, 11.)

Rods 0.7 by 2–3 microns. Gram positive. Non-motile. Usually in masses, rarely single. Bacteria from tissues not as pleomorphic as those from the earlier transfer cultures although many show polar granules or swollen ends. Cultures grown in broth show coccoid forms and beaded rods with swollen ends.

Gelatin: Grows poorly if at all. No liquefaction.

Agar: Small punctiform colonies.

Agar slants: Raised grayish white, and dry.

Blood serum slants: Fine gray punctiform colonies in 24 hrs. at 37°C.

which are a little larger than on agar. Streak scarcely 1 mm. in width. Glistening and slimy in fresh cultures. No liquefaction.

Litmus Milk: Reduction and coagulation from the bottom. Slow digestion of the casein.

Bouillon: Sediment at end of 2 days with clear bouillon above.

Potato: Growth grayish white, later becoming a dingy yellow, turning the potato bown.

Acid in dextrose. No acid in lactose, sucrose, maltose and mannitol.

Optimum temperature 37°C.

Habitat: Found in infections in pyelonephritis in cattle.

Genus III. Fusiformis *Hoelling, 1910.*

Obligate parasites. Anaerobic or microaerophilic. Cells frequently elongate and fusiform, staining somewhat unevenly. Filaments sometimes formed; non-branching. Non-motile. No spores formed. Growth in laboratory media feeble.

The type species is *Fusiformis termitidis* Hoelling.

1. **Fusiformis termitidis** Hoelling. (Arch. f. Protistenkunde, *19*, 1910, 239.)

Rods with pointed ends, with commonly two darkly staining granules which are suggestive of nuclei. Older forms show a greater number (as many as eight) of the granules. The cytoplasm at times shows an alveolar structure. The rods are 0.5 to 0.8 by 3.0 to 5.0 microns, the length increasing with the age of the organism. Gram-negative.

Habitat: Intestinal contents of termites.

2. **Fusiformis dentium** Hoelling. (Babes, Septische Prozesse des Kindesalters, 1889; Hoelling, Arch. f. Protistenkunde, *19*, 1910, 240.)

Rods with pointed ends, fusiform, 0.8 to 1.0 by 5 to 10 microns, showing from two to six deeply staining granules. Gram-positive.

Growth occurs on media, containing serum, under anaerobic conditions.

Serum dextrose agar: Yellowish-white colonies, with darker center from which lighter areas radiate toward the periphery; finely granular.

Serum broth: Turbid, with flocculent masses in fluid.

Litmus milk: Unchanged.

No growth in dextrose media.

The cultures have an offensive odor.

Anaerobic.

Optimum temperature 37°C.

Habitat: Oral cavity; associated with *Borrelia vincentii* in Vincent's angina, ulcerative stomatitis, gangrene, and in wounds. Not pathogenic for animals.

3. **Fusiformis nucleatus** (Knorr) Bergey et al. (*Fusobacterium nucleatum* Knorr, Cent. f. Bakt., I Abt., Orig., *89*, 1922, 17; Bergey et al., Manual, 3rd ed., 1930, 514.)

Rods with pointed ends, 1.0 by 4.0 microns in size. Show one or two granules.

Serum agar colonies: Large, gray, filamentous.

Serum broth: Turbid with flocculent sediment.

Anaerobic.

Optimum temperature 37°C.

Habitat: Oral cavity.

4. **Fusiformis polymorphus** (Knorr) Bergey et al. (*Fusobacterium polymorphum* Knorr, Cent. f. Bakt., I Abt., Orig., *89*, 1922, 19; Bergey et al., Manual, 1st ed., 1923, 206.)

Slender rods: 0.2 to 1.5 by 8 to 16 microns, occurring singly on solid media and in chains in liquid media.

Serum agar colonies: Gray, filamentous.

Serum broth: Turbid.

Anaerobic.

Optimum temperature 37°C.

Habitat: Oral cavity.

Genus IV. Cytophaga *Winogradsky, 1929.*

Rods, long, flexuous, with pointed ends, showing metachromatic granules. Incapable of using carbonaceous materials as food, except cellulose, which is hydrolyzed. Growth in ordinary culture media is feeble.

The type species is *Cytophaga hutchinsoni* Winogradsky.

1. **Cytophaga hutchinsoni** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 578.)

Rods, occurring singly and in chains, 0.3 to 0.4 by 3.0 to 8.0 microns. Show several deeply staining granules. Motility not demonstrated. Stain with difficulty. Gram-negative. Reproduction probable from the deeply staining granules (arthrospores?). Old cultures show large coccoid forms.

Grow on silica gel and attack cellulose in this medium forming big mucilaginous orange-colored colonies.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil. Disintegrates vegetable fiber.

2. **Cytophaga aurantiaca** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 597.)

Long rods with pointed ends, 1.0 by 6.0 to 8.0 microns. Non-motile. Gram-negative.

Forms rose-orange colored colonies on silica gel medium containing cellulose.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil. Disintegrates vegetable fiber.

3. **Cytophaga rubra** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 598.)

Long, slightly bent rods, 0.4 by 3.0 microns, with a small granule near each extremity. Motility not demonstrated. Gram-negative.

Grow on silica gel and attack cellulose forming red mucilaginous colonies.

Aerobic, facultative.

Optimum temperature.

Habitat: Soil. Disintegrates vegetable fiber.

4. **Cytophaga lutea** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 599.)

Rods: 0.4 by 3.0 microns. Gram-negative. Has not been isolated in pure culture.

Forms brilliant yellow mucilaginous colonies on cellulose in silica gel.

Habitat: Soil. Disintegrates vegetable fiber.

5. **Cytophaga ternissima** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 599.)

More slender than the other species.

Forms olive green mucilaginous colonies on silica gel containing cellulose.

Habitat: Soil.

Genus V. **Actinobacillus** Brumpt, 1910.*

Medium sized aerobic Gram-negative rods, staining poorly, sometimes forming threads and showing a tendency toward branching. Good growth on ordinary culture medium. Produce acid but no gas in carbohydrates. Cause diseases of animals which may be transmitted to man. The type species is *Actinobacillus lignieresi* Brumpt.

Key to the species of genus **Actinobacillus**

1. Nonmotile
   a. Growth slight or negative on potato
      1. *Actinobacillus lignieresi*
   aa. Good growth on potato
      2. *Actinobacillus mallei*
2. Motile
   a. Good growth on potato
      3. *Actinobacillus pseudomallei*

1. **Actinobacillus lignieresi** Brumpt. (Actinobacilo, Lignières and Spitz, Boletin d. Agri. y Ganaderia, Buenos Aires, *11*, 1902, 169; *Actinobacillus*, Lignières et Spitz, Cent. f. Bakt., I Abt., Orig., *35*, 1903, 294; Brumpt, Précis de parasitologie, Paris, 1910, 849; *Bacillus lignieri* Macé, Traité de Bacteriologie, 6th ed., *2*, 1913, 743.)

Rods: 0.4 by 1.0 to 15.0 microns. Non-motile. Gram-negative.

Gelatin colonies: Development indefinite.

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* *Pfeifferella* Buchanan, 1918 has been combined with *Actinobacillus* Brumpt, 1910 by Thompson, Jour. Bact., *26*, 1933, 226.

Gelatin stab: No liquefaction.

Agar colonies: Very small, bluish, translucent, becoming opaque, adherent.

Agar slant: Thin, bluish, slightly spreading.

Broth (seum): Turbid with thin pellicle.

Litmus milk: Acid, no coagulation.

Potato (alkaline): Slight yellowish growth.

Acid in dextrose and lactose.

Indol is formed.

Nitrates not reduced.

Aerobic.

Optimum temperature 37°C.

Habitat: Abscess formation in bovines, affecting principally the lymph nodes. Infectious for rabbits, cats, dogs, rats, pigs, chickens and pigeons.

2. **Actinobacillus mallei** (Flügge) Thompson. (Rotzbacillus, Löffler, Arbeiten aus dem Kaiserlichen Gesundheitsamte, *1*, 1886, 141; *Bacillus mallei* Flügge, Die Mikroorganismen, 1886, 222; *Pfeifferella mallei* Buchanan, Jour. of Bact., *3*, 1918, p. 54; *Brucella mallei* Pacheco, Revista da Sociedade paulista de Medicina veterinaria, *3*, 1933, 1; Thompson, Jour. Bact., *26*, 1933, 226; also Jour. Bact., *25*, 1933, 44.)

Common name: Glanders bacillus.

Small, slender rods, 0.25 to 0.4 by 1.5 to 3.0 microns, usually occurring singly, but may grow into long threads. Non-motile. Gram-negative.

Glycerin veal agar: Whitish, transparent layer.

Löffler's blood serum: Moist, opaque, slimy with yellowish-brown tinge.

Broth: Turbid, sometimes with thin pellicle, and more or less ropy sediment.

Litmus milk: Coagulated.

Potato: Moist, yellow, transparent (honey-like), becoming reddish-brown with age.

Indol not formed.

Nitrates not reduced.

Aerobic; facultative.

Optimum temperature 37°C.

Habitat: The cause of glanders, affecting horses, man, sheep, goats. Transmissible to dogs, cats, rabbits and guinea pigs.

3. **Actinobacillus pseudomallei** (Whitmore) Thompson. (*Bacillus pseudomallei* Whitmore, Jour. of Hyg., *13*, 1913, 1; *Bacillus whitmorei* Stanton and Fletcher, Trans. 4th. Cong. Far East Ass. Trop. Med., *2*, 1921, 196; Also, Jour. of Hyg., *23*, 1925, 347; *Flavobacterium pseudomallei* Bergey et al., Manual, 3rd ed., 1930, 146; Thompson, Jour. Bact., *26*, 1933, 226; also Jour. Bact., *25*, 1933, 44.)

Short rods with rounded ends, showing bipolar staining, occurring singly and in short chains. Motile. Gram-negative.

Gelatin stab: Moderate, crateriform liquefaction.

Agar colonies: Circular, slightly raised, thick, opaque, cream colored with irregular margin.

Glycerin agar slant: Wrinkled, thick, rugose, cream colored.

Broth: Turbid with pelicle.

Litmus milk: Curdling with slowly developed acidity, pink sediment.

Potatoe: Vigorous, cream colored.

Indol not formed.

Acid in dextrose, maltose, lactose, sucrose and mannitol.

Blood serum slowly liquefied.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Glanders-like infection (melioidiosis) in rats and in man in India.

Genus VI. **Mycoplana** *Gray and Thornton, 1928.*

Rods, motile or non-motile, showing branching cells. Capable of using aromatic compounds, as phenol, etc. as a source of energy. Occur in soil.

Type species *Mycoplana dimorpha* Gray and Thornton.

Key to the species of genus **Mycoplana.**

a. Gelatin not liquefied.
   1. *Mycoplana dimorpha.*

aa. Gelatin liquefied.
   2. *Mycoplana bullata.*

1. **Mycoplana dimorpha** Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 82.)

Short, curved and irregular rods, 0.5 to 0.7 by 1.25 to 4.5 microns, occasionally showing branching. Motile, with long polar flagella. Gram-negative.

Gelatin colonies: Circular, buff, smooth, resinous, entire.

Gelatin stab: No liquefaction.

Agar colonies: Circular, buff, convex, smooth, glistening, entire.

Agar slant: Filiform, white, convex, glistening, entire.

Broth: Turbid with surface ring.

Litmus milk.

Potato.

Indol.

Nitrates reduced to nitrites.

Starch hydrolyzed.

No action in carbohydrate media.

Attacks phenol.

Aerobic.

Optimum temperature 30° to 35°C.

Habitat: Soil.

2. **Mycoplana bullata** Gray and Thornton. (Cent. f. Bakt., II Abt., *73*, 1928, 83.)

Rods, curved and irregular, branching, 0.8 to 1.0 by 2.25 to 4.5 microns. Motile with polar flagella. Gram-negative.

Gelatin colonies: Circular, buff, smooth, glistening, edge diffuse. Partially liquefied.

Gelatin stab: Saccate liquefaction.

Agar colonies: Circular, white, convex, smooth, glistening, entire.

Agar slant: Filiform, white, convex, smooth, glistening, entire.

Broth: Turbid.

Litmus milk.

Potato.

Indol not formed.

Nitrates not reduced. Gas in fermentation tube.

Starch not hydrolyzed.

No acid in carbohydrate media.

Attacks phenol.

Aerobic.

Optimum temperature 30° to 35°C.

Habitat: Soil.

Genus VII. **Cellvibrio** *Winogradsky, 1929.*

Long rods, slightly curved, with rounded ends, show deeply staining granules (arthrospores?) which appear to be concerned in reproduction. Motile with a polar flagellum. Oxidize cellulose, forming oxycellulose. Growth on ordinary culture media is feeble.

The type species is *Cellvibrio ochraceus* Winogradsky.

1. **Cellvibrio ochraceus** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 549, 601.)

Plump, curved rods with rounded ends, 0.5 by 2.5 to 5.0 microns, rarely occurring as spirals. Motile. Gram-negative.

Produces diffuse, light ochre-colored, mucilaginous colonies on cellulose silica gel medium.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil. Disintegrates vegetable fiber.

2. **Cellvibrio flavescens** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 608.)

Plump, curved rods with rounded ends. Shows metachromatic granules. Motile. Gram-negative.

Produces diffuse, light yellow, mucilaginous colonies on cellulose silica gel medium.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil. Disintegrates vegetable fiber.

Genus VIII. Cellfalcicula *Winogradsky, 1929.*

Short rods, not exceeding 2.0 microns in length, with pointed ends. Show metachromatic granules. Old cultures show coccoid forms. Motile with a single polar flagellum. Oxidize cellulose, forming oxycellulose. Growth on ordinary culture media is feeble.

The type species is *Cellfalcicula viridis* Winogradsky.

1. **Cellfalcicula viridis** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 616.)

Plump, curved rods, 0.7 by 2.0 microns, with slightly pointed ends. Motile. Gram-negative. Produces diffuse green, mucilaginous colonies on cellulose silica gel medium.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

2. **Cellfalcicula mucosa** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 621.)

Plump, curved rods, 0.7 by 2.0 microns, with slightly pointed ends. Motile. Gram-negative.

Produces diffuse, cream-colored, mucilaginous colonies on cellulose silica gel medium.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

3. **Cellfalcicula fusca** Winogradsky. (Ann. de l'Inst. Pasteur, *43*, 1929, 622.)

Plump, curved rods, 0.7 by 2.0 microns, with slightly pointed ends. Motile. Gram-negative.

Produces diffuse, cream-colored, mucilaginous colonies on cellulose silica gel medium.

Aerobic, facultative.

Optimum temperature 20°C.

Habitat: Soil.

ORDER III. CHLAMYDOBACTERIALES BUCHANAN, 1918.

Filamentous bacteria, alga-like, typically water forms, frequently sheathed, without true branching although false branching may be present. The sheath is frequently impregnated with iron. Conidia may be developed, but never endospores. Sulfur granules or bacteriopurpurin never present. Mature cells or filaments not motile nor protozoan-like.

The order contains a single family.

FAMILY I. CHLAMYDOBACTERIACEAE MIGULA, 1894.

Key to the genera of family **Chlamydobacteriaceae.**

1. Filaments usually not permanently attached.
   a. Filaments straight or at least not twisted.
      Genus I. *Leptothrix*, p. 564.
   b. Filaments twisted.
      Genus II. *Didymohelix*, p. 564.
2. Filaments attached.
   a. Filaments unbranched.
      Genus III. *Crenothrix*, p. 566.
   b. Filaments show pseudodichotomous branching.
      1. Swarm cells developed (motile conidia). Usually without a deposit of iron in the sheath.
         Genus IV. *Sphaerotilus*, p. 566.
      2. Spherical, non-motile conidia. Usually with iron oxide.
         Genus V. *Clonothrix*, p. 567.

Genus I. Leptothrix *Kützing, 1843.*

Filaments of cylindrical, colorless cells, with a sheath at first thin and colorless, later thicker, yellow or brown, becoming encrusted with iron oxide. The iron may be dissolved by dilute acid, whereupon the inner cells show up well. Multiplication is through the division and abstraction of cells and motile, cylindric swarm cells. Swarm cells sometimes germinate in the sheath giving the appearance of branching. Pseudodichotomous branching may occur.

The type species is *Leptothrix ochracea* Kützing.

Key to the species of genus **Leptothrix.**

a. Sheath yellow, becoming brown.
   1. *Leptothrix ochracea.*
b. Sheath thick, slimy.
   2. *Leptothrix epiphitica.*
c. Sheath soft, enclosing very slender filaments.
   3. *Leptothrix fluitans.*
d. Sheath absent, filaments not segmented.
   4. *Leptothrix hyalina.*

1. **Leptothrix ochracea** Kützing. (Phycologica Generalis, 1843, 198; *Chlamydothrix ochracea* Migula, System der Bakterien, 1900, 1031.)

Filaments 0.8 micron in thickness, composed of rod-like, colorless cells, surrounded by a delicate sheath. Later the sheath becomes thicker, yellow to brown in color. Short, non-motile, ovoid conidia are set free at the apex of a filament. The sheath contains hydrated oxide of iron. Pseudodichotomous branching occurs. Does not grow on ordinary culture media.

Habitat: In water containing iron (widely distributed).

2. **Leptothrix epiphitica** (Migula) Bergey et al. (*Streptothrix epiphitica* Migula, Schizomyceten, Engler und Prantl's Nat. Pflanzenfamilien, *1*, 1a, 1895, 38; *Chlamydothrix epiphitica* Migula, System der Bakterien, 1900, 1033; Bergey et al., Manual, 1st ed., 1923, 391.)

Short, colorless filaments, enclosed in a thick, slimy sheath. Attached to algae.

Habitat: In water containing iron (widely distributed).

3. **Leptothrix fluitans** (Migula) Bergey et al. (*Streptothrix fluitans* Migula, Engler und Prantl's Nat. Pflanzenfamilien, *1*, 1a, 1895, 38; *Chlamydothrix fluitans* Migula, System der Bakterien, 1900, 1033; Bergey et al., Manual, 1st ed., 1923, 391.)

Very thin filaments up to 1 centimeter in length, surrounded by a soft sheath, from which almost spherical conidia issue, usually attaching themselves to the exterior of the sheath where they multiply.

Habitat: Swamp water.

4. **Leptothrix hyalina** (Migula) Bergey et al. (*Streptothrix hyalina* Migula in Engler und Prantl's Nat. Pflanzenfamilien, *1*, 1a, 1895, 38; *Chlamydothrix hyalina* Migula, System der Bakterien, 1900, 1033; Bergey et al., Manual, 1st ed., 1923, 391.)

Slender filaments, barely 0.6 micron in thickness, occurring in small tufts. No sheath is formed. No segmentation of the filaments can be observed.

Habitat: Swamp water.

Genus II. Didymohelix *Griffith, 1853.*

Filaments twisted, simple, or two filaments twisted together. Young cells colorless, later brown to rust-red through deposition of iron. Simple filaments show no division into cells, even when iron is removed with acid and stain applied. Sheath not demonstrable.

The type species is *Didymohelix ferruginea* (Ehrenberg) Griffith.

1. **Didymohelix ferruginea** (Ehrenberg) Griffith. (*Gallionella ferruginea* Ehrenberg, Poggendorf's Annalen, II Reihe, 8, 1836, 217; *Gloeotila ferruginea* Kützing, Species Algarum, 1849, 363; Griffith, Ann. and Mag. Nat. Hist., Ser. 2, *12*, 1853, 438; *Spirulina ferruginea* Kirchner, Algen, Kryptogamen Flora v. Schlesien, *2*, 1, 1878, 250; *Gloeosphaera ferruginea* Rabenhorst; *Chlamydothrix ferruginea* Migula, System der Bakterien, 1900, 1031.)

Thin, yellowish-brown filaments in which separation into single cells cannot be definitely differentiated. Under the microscope the filaments appear to be of two kinds; the one consisting of extremely delicate, irregularly bent, yellowish threads about 1.0 micron in thickness, lying separate or in small masses; the other consisting of filaments separated into single elements arranged in chains, about 2.0 microns in thickness, occurring singly or in masses. Higher magnification shows that the supposed chains are in reality spirals formed of two cells becoming intertwined. Fresh specimens treated with iodin solution show the presence of a sheath.

Habitat: Water containing iron.

Genus III. **Crenothrix** *Cohn, 1870.*

Filaments unbranched, showing differentiation of base and tip, attached, usually thicker at the tip. Sheaths plainly visible usually colorless, but brownish from iron oxide in old filaments. Cells cylindrical or spherical. Multiplication by non-motile, spherical conidia; cells dividing in three planes to form conidia.

The type (and only) species is *Crenothrix polyspora* Cohn.

1. **Crenothrix polyspora** Cohn. (Beiträge z. Biol., *1*, Heft I, 1870, 108.)

Long, stiff, unbranched filaments, segmented, the young filaments with a thin, and the older filaments with a thick sheath. The sheath contains a deposit of iron oxide. The filaments are 1.5 to 5.2 microns in thickness. Vegetating cells are from one-half to four times the thickness of the filaments. Two kinds of conidia are formed: microconidia, formed by the segmentation of the vegetating cells, producing small, spherical elements; and macroconidia, produced by the vegetating cells near the apex of the filaments by breaking up into large oval elements. The conidia may either escape or germinate within the filaments.

Does not grow on artificial media.

Habitat: In stagnant and running water containing organic matter and iron salts, growing as thick masses of a brownish or greenish color.

Genus IV. **Sphaerotilus** *Kützing, 1833.*

Attached, colorless threads, showing false branching, making a pseudodichotomy. Filaments consist of rod-shaped or oval cells, surrounded by a thin, firm sheath. Multiplication occurs both by non-motile and motile conidia, the latter with a clump of flagella near one end.

The type species is *Sphaerotilus natans* Kützing.

1. **Sphaerotilus natans** Kützing. (Linnaea, *8*, 1833, 385.)

Cells cylindrical, surrounded by a sheath which is slimy in character and difficult to detect, about 2.0 microns in thickness and of variable length. Multiplication occurs through the formation of conidia within the sheath of the vegetative cells, from which they swarm at one end, float about for a time, and then attach themselves to objects and develop into delicate filaments.

Habitat: Stagnant water.

2. **Sphaerotilus dichotomus** (Cohn) Migula. (*Cladothrix dichotoma* Cohn, Beitrage z. Biol., *1*, Heft III, 1875, 185; Migula, System der Bakteria, 1900, 1033.)

Filaments 2.0 microns in thickness and of variable lengths, exhibiting dichotomous branching. The filaments segment within the sheath into straight or spiral, motile bodies which emerge from the apex or break through the sheath.

Gelatin colonies: In four to five days, small, yellowish, becoming brownish, with whitish surface. The surrounding medium turns brown.

Gelatin stab: Thin, grayish surface growth. Medium is slowly liquefied, becoming brown.

Aerobic.

Optimum temperature 25° to 30°C.

Habitat: Swamp water.

Genus V. **Clonothrix** *Schorler, 1904.*

Filaments with false, dichotomous or irregular branching, attached, with contrast of base and tip, thicker at the base and tapering to the tip. Sheath always present, thin on young filaments, later becoming thicker and encrusted with iron and manganese. Multiplication by small, non-motile conidia of spherical form, formed from the disc-shaped cells near the tip by longitudinal division and rounding up.

The type species is *Clonothrix fusca* Schorler.

1. **Clonothrix fusca** Schorler. (Cent. f. Bakt., II Abt., *12*, 1904, 689.)

Branching filaments, 5 to 7 microns in thickness at base (with the sheath), and tapering to 2 microns. The filaments range from colorless to dark, yellowish-brown, according to age. Iron hydroxide is stored in the sheath.

Habitat: Water.

ORDER IV. THIOBACTERIALES BUCHANAN, 1918.

Cells various, typically containing either granules of free sulfur, or bacteriopurpurin, or both, usually growing best in the presence of hydrogen sulfid. The cells are plant-like, not protozoan-like, not producing a pseudoplasmodium or a highly developed resting stage. Spores are rarely or never formed.

Key to the families of the order **Thiobacteriales.**

A. Cells containing bacteriopurpurin with or without sulfur granules.
    Family I. *Rhodobacteriaceae*, p. 567.
B. Cells containing sulfur granules (or in one species possibly oxalate crystals) but no bacteriopurpurin.
    1. Filamentous forms.
        Family II. *Beggiatoaceae*, p. 582.
    2. Unicellular, motile forms. Not filamentous.
        Family III. *Achromatiaceae*, p. 585.

FAMILY I. RHODOBACTERIACEAE MIGULA, 1900.

Cells of various types, not filamentous, containing bacteriopurpurin, with or without sulfur granules.

According to Molisch, Die Purpurbakterien, Jena, 1907, 64, very few species of this family have been studied in pure culture. Those that have been isolated and studied were found to be able to exist saprophytically and were not able to exist without organic matter.

Two subfamilies may be separated by the following key:

Key to the subfamilies of family **Rhodobacteriaceae.**

A. Cells containing sulfur granules.
Subfamily I. *Chromatioideae*, p. 568.
B. Cells without sulfur granules.
Subfamily II. *Rhodobacterioideae*, p. 579.

SUBFAMILY I. CHROMATIOIDEAE BUCHANAN, 1918.

Synonym: *Thiorhodaceae* Molisch.

Cells not filamentous, containing both sulfur granules and bacteriopurpurin.

Key to the tribes of the subfamily **Chromatioideae.**

A. Cells united, at least during a part of the life history, into families.
I. Cell division such that masses of cells, not merely plates, are formed.
a. Cell division in three directions of space.
Tribe I. *Thiocapseae*, p. 568.
aa. Cell division first in three, then in two directions of space.
Tribe II. *Lamprocysteae*, p. 570.
II. Cell division in two planes, forming plates of cells.
Tribe III. *Thiopedieae*, p. 571.
III. Cell division in one plane.
Tribe IV. *Amoebobacterieae*, p. 572.
AA. Cells free, capable of swarming at any time.
Tribe V. *Chromatieae*, p. 574.

TRIBE I. THIOCAPSEAE BUCHANAN, 1918

Bacteria containing both sulfur granules and bacteriopurpurin. Cells divide in three directions of space, united into families.

Key to the genera of Tribe **Thiocapseae.**

A. Cells capable of swarming.
1. Families small, compact, enclosed, singly or several together, in a cyst.
Genus I. *Thiocystis*, p. 569.
2. Cells large, 7 to 8 microns, loosely bound by gelatin into families
Genus II. *Thiosphaera*, p. 569.
3. Cells small, united into solid, spherical families.
Genus III. *Thiosphaerion*, p. 569.
B. Cells not capable of swarming.
1. Spherical cells spread out upon the substratum in flat families, loosely enveloped in a common gelatin.
Genus IV. *Thiocapsa*, p. 570.

2. Arranged in regular packets like Sarcina.
Genus V. *Thiosarcina*, p. 525.

Genus I. Thiocystis *Winogradsky, 1888.*

Usually 4 to 30 cells massed into small, compact families, enveloped singly or several together in a gelatinous cyst, capable of swarming. When the families have reached a definite size they escape from the gelatinous cyst, the latter swelling and softening uniformly or at some particular spot. The escaped cells either pass into the swarm stage or unite into a large fused complex of families from which they separate later. Cells are light colored, single cells almost colorless. In masses the cells show a beautiful violet or red color. The cells are frequently filled with sulfur granules.

The type species is *Thiocystis violacea* Winogradsky.

1. **Thiocystis violacea** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 65.)

Cells spherical, 2.7 to 5.2 microns in size. The families are associated in thick, encysted mass. Color, bright red or reddish-violet.

Habitat: Water.

2. **Thiocystis rufa** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 65.)

Cells spherical, very small, not more than 1.0 micron in size. Families in the cysts are packed much more closely than in Thiocystis violacea. Color, intense violet, red or brownish-red, and in large masses, black.

Habitat: Water.

Genus II. Thiosphaera *Miyoshi, 1897.*

Cells spherical-ellipsoidal, relatively large (7 to 8 microns), light violet in color, bound into loose families by a colorless gelatin. Capable of swarming. Sulfur inclusions relatively abundant.

The type species is *Thiosphaera gelatinosa* Miyoshi.

1. **Thiosphaera gelatinosa** Miyoshi. (Jour. Col. Science, Imp. University of Tokyo, 1897, 170.)

Cells sphaero-elliptical, 5 by 7 microns in size, of light violet color, united into loose aggregations by a colorless gelatinous material. Contain fairly numerous sulfur granules. Swarming.

Habitat: In slimy sediment in water.

Genus III. Thiosphaerion *Miyoshi, 1897.*

Cells spherical-elliptical, small (1.8 to 2.5 microns) violet in color, with delicate sulfur inclusions. United by means of gelatin into solid spherical families. Capable of swarming.

1. **Thiosphaerion violaceum** Miyoshi. (Jour. Col. Science, Imp. University of Tokyo, 1897, 170.)

Cells sphaero-elliptical, 1.8 by 2.5 microns in size, violet in color, with sulfur granules. United into dense, globose masses by means of gelatinous material. Swarming.

Habitat: In thermal springs.

Genus IV. Thiocapsa *Winogradsky, 1888.*

Cell families resembling, in grouping and multiplication, the cells of the alga genus *Aphanocapsa*. Cell division occurs in all directions of space, the cells are spherical, with thick, confluent membranes, which unite to form a structureless, gelatinous layer. The cells are of a bright rose-red color and contain sulfur granules. The cells do not swarm.

The type species is *Thiocapsa roseopersicina* Winogradsky.

1. **Thiocapsa roseopersicina** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterin, 1888, 84.)

Spherical cells with thick, confluent membrane which is generally structureless. The plasma is colored intensely red and rich in large sulfur granules, sometimes reaching 2.8 microns in size.

Habitat: Water.

Genus V. Thiosarcina *Winogradsky, 1888.*

Non-swarming cells arranged in packet-shaped families, corresponding to the genus *Sarcina*. Cells red, with sulfur granules.

The type species is *Thiosarcina rosea* (Schroeter) Winogradsky.

1. **Thiosarcina rosea** (Schroeter) Winogradsky. (*Sarcina rosea* Schroeter, Kryptog. Flora von Schlesien, *3*, I, 1886, 154; Winogradsky, Bot. Zeitung, 1887; I. Schwefelbakterien, 1888, 104.)

Cells spherical, 2.0 to 2.5 microns in diameter, aggregated in small, broad masses.

Habitat: Swamp water.

TRIBE II. LAMPROCYSTEAE BUCHANAN, 1918.

Cells united into families in which division of the cells occurs first in three planes, then in two.

The single genus of this tribe is *Lamprocystis* Schroeter.

Genus I. Lamprocystis *Schröter, 1886.*

Cells ellipsoidal, dividing at first in three planes to form spherical cell masses, later in two planes, forming hollow sacks in which the cells lie embedded in a layer in the walls; finally the membrane ruptures, and the whole mass becomes net-like, much as in the algal genus *Clathrocystis*. Usually colored intensely violet. Small, sulfur granules present. Capable of swarming.

The type species is *Lamprocystis roseopersicina* (Kützing) Schröter.

1. **Lamprocystis roseopersicina** (Kützing) Schroeter. (*Protococcus roseopersicina* Kützing, Species Algarum, 1849, 3; Schroeter, Kryptog. Flora von Schlesien, *3*, I, 1886, 151.)

Cells spherical or slightly elliptical, 2.1 microns in diameter, almost twice as large before undergoing fission. Color, in masses, fairly intensive violet.

Habitat: Water.

TRIBE III. THIOPEDIEAE BUCHANAN, 1918.

Sulfur bacteria in which the cells are united into families, and cell division occurs in two directions of space, resulting in the development of plates of cells.

The genera may be differentiated by the following key:

Key to the genera of tribe **Thiopedieae.**

A. Cells occurring in a film or membrane, the arrangement into tetrads being less evident along the periphery of the masses.
  a. Cells are surrounded by a gelatinous substance.
    Genus I. *Thiopedia*, p. 571.
  b. Cells united into flat or tubular masses.
    Genus II. *Thioderma*, p. 571.

AA. Cells occurring regularly in fours.
    Genus III. *Lampropedia*, p. 572.

Genus I. Thiopedia *Winogradsky, 1888.*

Families in form of plates. Capable of swarming. Cells contain bacteriopurpurin and bacteriochlorin.

The type species is *Thiopedia rosea* Winogradsky.

I. **Thiopedia** rosea Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, Heft I, Schwefelbakterien, 1888, 85).

Cells spherical, 1.1 to 2.0 microns in size, united by a gelatinous substance into a film or membrane, or into more or less irregular masses. The organisms are very pale, but in masses show a slight rose color.

Habitat: Swamp water.

Genus II. Thioderma *Miyoshi, 1897.*

Cells spherical, light rose in color, containing small, inconspicuous sulfur granules. United by a thin, purplish membrane.

The type species is *Thioderma rosea* Miyoshi.

1. **Thioderma rosea** Miyoshi. (Jour. Col. Science, Imperial University of Tokyo, 1897, 170.)

Cells spheroidal, 1.5 to 2.5 microns in size. Color pale red with minute sulfur granules. Encysted in thin, purplish-red membrane. Capable of swarming.

Habitat: Thermal springs.

Genus III. **Lampropedia** *Schröter, 1886.*

Cells united into tetrads, forming flat, tubular masses, contain sulfur granules and bacteriopurpurin.

The type species is *Lampropedia hyalina* (Kützing) Schroeter.

1. **Lampropedia hyalina** (Kützing) Schroeter. (Kryptogamenflora von Schlesien, *3*, I, 1886, 151.)

Cells spherical, colorless, about 2.0 microns in diameter, grouped in fours or multiples of fours into masses 15 microns in size. Has not been cultivated.

Habitat: Swamp water and in decomposing materials from sugar refineries.

TRIBE IV. AMOEBOBACTERIEAE BUCHANAN, 1918.

Sulfur bacteria in which the cells are united into families. Cell division occurring only in one direction of space.

Key to the genera of tribe **Amoebobacterieae.**

A. Cells connected by plasma threads; families amoeboid, motile.
Genus I. *Amoebobacter*, p. 572.

B. Cells not as in A.
  1. Cells arranged in a net, united by their ends.
  Genus II. *Thiodictyon*, p. 573.
  2. Cells not arranged in a net.
    a. Capable of swarming, cells loosely aggregated in gelatin.
    Genus III. *Thiothece*, p. 573.
    b. Non-motile. Cells appressed into a colony.
    Genus IV. *Thiopolycoccus*, p. 573.

Genus I. **Amoebobacter** *Winogradsky, 1888.*

Cells connected by plasma threads. Families amoeboid, motile. The cell families slowly change form, the cells drawing together into a heap or spreading out widely, thus bringing about a change in the shape of the whole family. In a resting condition a common gelatin is extruded, the surface becomes a firm membrane.

The type species is *Amoebobacter roseum* Winogradsky.

1. **Amoebobacter roseum** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 77.)

Cells spherical, 2.8 to 3.4 microns in diameter; before fission, up to 6.0 microns in diameter. Color, pale rose; in masses, lilac.

Habitat: Water.

2. **Amoebobacter bacillosum** Winogradsky. (Beitrage zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 78.)

Cells elongated 1.7 by 2.4 microns; single cells almost colorless, in families, red. A vacuole, filled with nearly transparent substance, is seen, even in the vegetative stage. The cell plasma contains only occasional, punctiform sulfur granules.

Habitat: Water.

3. **Amoebobacter granulae** Winogradsky. (Beitrage zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 78.)

Cells spherical, small, scarcely 0.5 micron in diameter. Colorless. Contain a single, small sulfur granule.

Habitat: Water.

Genus II. Thiodictyon *Winogradsky, 1888.*

Cells rod-shaped or spindle-shaped, with sharply pointed ends, united into a net. The compact mass of rods finally assumes an appearance like that of *Hydrodictyon.* Slight violet color.

The type species is *Thiodictyon elegans* Winogradsky.

1. **Thiodictyon elegans** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 82.)

Thin, spindle-shaped rods with pointed ends, 1.7 by 5.0 microns. The plasma is distributed in a thin layer along the wall of the cell and contains punctiform sulfur granules. Color, slight.

Habitat: Water.

Genus III. Thiothece *Winogradsky, 1888.*

Cells spherical, in families, enclosed in a thick, gelatinous cyst. Cells capable of swarming and very loosely embedded in a common gelatin. When the swarm stage supervenes the cells lie more loosely, the gelatin is swollen, and the cells swarm out singly and rather irregularly.

The type species is *Thiothece gelatinosa* Winogradsky.

1. **Thiothece gelatinosa** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 82.)

Cells spherical to long cylindrical-elliptical, encysted in a thick membrane in masses 4.2 microns in diameter. Color, intense grayish-violet to light rose. Sulfur granules very small, of equal size, and uniformly distributed in the cell.

Habitat: Water.

Genus IV. Thiopolycoccus *Winogradsky, 1888.*

Families solid, non-motile, consisting of small cells closely appressed. Multiplication of the colonies by breaking up of the surface into numerous, short threads and lobes which continue to split up into smaller heaps.

The type species is *Thiopolycoccus ruber* Winogradsky.

1. **Thiopolycoccus ruber** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 79.)

Cells spherical, 1.2 microns in diameter. Contain fairly large sulfur granules. Color in thick masses, intense red.

Habitat: Water.

TRIBE V. CHROMATIEAE BUCHANAN, 1918.

Sulfur bacteria in which the cells are not united into families, but free and capable of swarming at any time.

Key to the genera of tribe **Chromatieae.**

A. Cells motile by means of polar flagella. Elongated.
  1. Cells not spiral.
    a. Cells cylindrical.
      Genus I. *Chromatium*, p. 574.
    b. Cells with tendency to spindle shape.
      Genus II. *Rhabdomonas*, p. 576.
  2. Cells spiral.
      Genus III. *Thiospirillum*, p. 577.

B. Cells spherical or little elongate. Non-motile.
  1. Cells not encapsulated.
      Genus IV. *Rhodocapsa*, p. 578.
  2. Cells encapsulated in pairs.
      Genus V. *Rhodothece*, p. 578.

Genus I. **Chromatium** *Perty, 1852.*

Cells cylindrical-elliptical or relatively thick cylindrical. Cell contents red, containing dark sulfur granules. Cells somewhat variable in shape, straight, more or less bent, short ovoid and longer forms more cylindrical. Motile by means of polar flagella.

The type species is *Chromatium okenii* Perty.

Key to the species of genus **Chromatium.**

1. Cells cylindrical.
  a. Cell content rose-color.
      1. *Chromatium okenii.*
  b. Cells violet or brownish.
      2. *Chromatium weisii.*
      3. *Chromatium violaceum.*
      4. *Chromatium minus.*
  c. Cells red with dark red granules at ends.
      5. *Chromatium warmingii.*

2. Cells elliptical.
   a. Single cells colorless, masses of cells reddish-violet.
      6. *Chromatium minutissimum.*
      7. *Chromatium vinosum.*
3. Cells spiral.
      8. *Chromatium lipoferum.*

1. **Chromatium okenii** Perty. (Zur kentniss Kleinster Lebensformen, 1852, 174.)

Cells cylindrical, 5 to 6 by 7.5 to 15 microns, with rounded ends. Motile with, usually three, flagella at one or both poles. Cell content is rose in color.

Habitat: Swamps.

2. **Chromatium weisii** Perty. (Zur kentniss Kleinster Lebensformen, 1852, 174.)

Cells cylindrical, 4.2 by 5.7 to 11.5 microns. Color violet or brownish.

Habitat: Water.

3. **Chromatium violaceum** Perty. (Zur kentniss Kleinster Lebensformen, 1852, 174.)

Cells spherical or elliptical, transparent, faintly violet in color, 2 to 3 microns in length.

Habitat: Water.

4. **Chromatium minus** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 99.)

Cells cylindrical, 3.0 by 3.7 microns. Resembles *Chromatium weisii.*

Habitat: Water.

5. **Chromatium warmingii** (Cohn) Migula. (Cohn, Beiträge zur Biologie, *1*, Heft III, 1875, 167; Migula, System der Bakterien, 1900.)

Cells resembling *Chromatium okenii* but somewhat more robust. The cell wall is colorless. The plasma is red with dark red granules at each end. Size 8 by 15 to 20 microns.

Habitat: Water.

6. **Chromatium minutissimum** Winogradsky. (Beiträge zur Morphologie und Physiologie, der Bakterien, I. Schwefelbakterien, 1888, 100.)

Cells elliptical to cylindrical, 1 to 1.2 microns in size. Single cells colorless, masses reddish violet. A very small sulfur granule is located in the center of the cell.

Habitat: Water.

7. **Chromatium vinosum** (Ehrenberg) Winogradsky. (Ehrenberg, Infusionstierchen, 1838; Winogradsky, Beiträge zur Morphologie und Physiologie, der Bakterien, I. Schwefelbakterien, 1888, 99.)

Elliptical cells, 2.1 by 5 microns. Masses are reddish-violet in color. Actively motile.

Habitat: Water.

8. **Chromatium lipoferum** (Beijerinck) Bergey et al. (*Spirillum lipoferum* Beijerinck, Cent. f. Bakt., II Abt., *63*, 1925, 353; Bergey et al., Manual, 3rd ed., 1930, 531.)

Curved cells with one-half to one spiral turn, containing minute fat droplets. Motile with leptotrichous flagella. Gram-negative.

Ca-malate agar colonies: Circular, small, transparent, dry. The malate is oxidized to calcium carbonate.

Peptone agar colonies: More abundant development.

Fix atmospheric nitrogen.

Aerobic.

Optimum temperature 22°C.

Habitat: Garden soil.

Genus II. **Rhabdomonas** *Cohn, 1875.*

Differentiated from *Chromatium* by the elongated rod-shaped or spindle. shaped cells. Cells red, with sulfur granules, and flagella.

The type species is *Rhabdomonas rosea* Cohn.

Key to the species of genus **Rhabdomonas.**

I. Cells spindle-shaped.
- a. Cells rose colored.
  - 1. Cells large, united in chains.
    - 1. *Rhabdomonas rosea.*
  - 2. Cells smaller, sulfur content insignificant.
    - 2. *Rhabdomonas minor.*
  - 3. Cells with sharply pointed ends.
    - 3. *Rhabdomonas fusiformis.*

II. Cells cylindrical.
- a. Cells rose-colored.
  - 1. Contain sulfur granules of variable size.
    - 4. *Rhabdomonas gracilis.*

1. **Rhabdomonas rosea** Cohn. (Beiträge zur Biol. d. Pflanzen, *1*, Heft III, 1875, 167.)

Cells spindle shaped, of irregular thickness, 3.6 to 5.0 microns in length, occurring in threads of 10 to 30 members. The cells usually remain attached to each other and become indented before undergoing fission. Color red.

Habitat: Water.

2. **Rhabdomonas minor** Winogradsky. (Beiträge zur Morphologie un Physiologie der Bakterien, I. Schwefelbakterien, 1888, 102.)

Cells much smaller than *Rhabdomonas rosea*, 2.0 to 2.9 by 5 to 10 microns. Color, bright rose red. Sulfur content insignificant.

Habitat: Water.

3. **Rhabdomonas fusiformis** Winogradsky. (Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888, 102.)

Cells spindle-shaped with sharply-pointed ends, the greatest thickness is 8.5 microns by 25 to 50 microns in length.

Habitat: Water.

4. **Rhabdomonas gracilis** (Warming) Migula. (*Monas gracilis* Warming, Videnskabelige, Meddelelser fra den naturhistorishe Forening, Kjöbenhavn, 1876, 27; Migula, System der Bakterien, 1900, 1049.)

Cells cylindrical, frequently thicker at one end, 2.0 by 60 microns, with rounded ends. Plasma rose red and contains sulfur granules of variable size. Motile with polar flagella.

Habitat: Water.

Genus III. Thiospirillum *Winogradsky, 1888.*

Spiral, motile bacteria containing sulfur granules and bacteriopurpurin. The type species is *Thiospirillum sanguineum* (Ehrenberg) Winogradsky.

Key to the species of genus Thiospirillum.

1. Cell content bright red with numerous red granules.
   1. *Thiospirillum sanguineum.*
   2. *Thiospirillum rufum.*
2. Cell content olive-brown.
   3. *Thiospirillum jenense.*
3. Cell content dirty violet.
   4. *Thiospirillum violaceum.*
4. Cell content dark, even between the sulfur granules.
   5. *Thiospirillum rosenbergii.*

1. **Thiospirillum sanguineum** (Ehrenberg) Winogradsky. (*Ophidiomonas sanguinea* Ehrenberg, Cohn, Beiträge zur Biol. d. Pflanzen, *1*, Heft III, 1875, 169; Winogradsky, Beiträge zur Morphologie und Physiologie der Bakterien, I. Schwefelbakterien, 1888.)

Motile, rigid, spirals, 3.0 microns in thickness, spirals 6 to 9 microns in diameter and bright red with numerous granules having a reddish shimmer. Tufts of flagella at the poles.

Habitat: Water.

2. **Thiospirillum rufum** (Perty) Winogradsky. (*Spirillum rufum* Perty, Zur kentniss Kleinster Lebensformen, 1852, 179; Winogradsky, Beiträge z. Morph. u. Physiol. d. Bakt., I. Schwefelbakterien, 1888.)

Spirals of the form and size of *Spirillum undula*. Color red. Tufts of curly polar flagella.

Habitat: Water.

3. **Thiospirillum jenense** (Ehrenberg) Winogradsky. (*Ophidiomonas jenensis* Ehrenberg, Infusionstierchen, 1838, 44; Winogradsky, Beiträge z. Morph. u. Physiol. d. Bakt., I. Schwefelbakterien, 1888.)

Motile, rigid spirals, 3.5 microns in thickness with one-half to two and one-half windings. Cell content olive brown in color.

Habitat: Water.

4. **Thiospirillum violaceum** (Warming) Migula. (*Spirillum violaceum* Warming, Videnskabelige Meddelelser fra den naturhistoriske Forening, Kjöbenhavn, 1876, 21; Migula, System der Bakterien, 1900, 1050.)

The simplest forms are half moon to ring form, the fully developed forms show a sharply wound screw. The ends are rounded. Cell content, dirty violet in color with occasional sulfur granules. The height of the screw is 8 to 10 microns, the diameter 1.0 to 1.5 microns, the thickness of the cells 3 to 4 microns. Actively motile.

Habitat: Sea water.

5. **Thiospirillum rosenbergii** (Warming) Migula. (*Spirillum rosenbergii* Warming, Videnskabelige Meddelelser fra den naturhistoriske Forening, Kjöbenhavn, 1876, 42; Migula, System der Bakterien, 1900, 1050.)

Cells with almost a complete screw turn, 1.5 to 2.6 microns in thickness, usually less in length, height of screw 6 to 7.5 microns; total length 12 microns. The form varies from a rigid S-form to a screw of about half the diameter of the height. Usually filled with granules. The plasma appears dark, even between the granules.

Habitat: Sea water.

Genus IV. Rhodocapsa *Molisch, 1906.*

Cells free (not united in families) not capable of swarming (non-motile). In mass, the organisms are cherry red. Contain sulfur granules.

The type species is *Rhodocapsa suspensa* Molisch.

1. **Rhodocapsa suspensa** Molisch. (Die Purpurbakterien, Jena, 1907, 17.)

Rods or filaments, 1.8 to 3.5 by 3.5 to 180 microns. Encapsulated. The cells show red, motile granules. At times sulfur granules are also present. Bacteriopurpurin and bacteriochlorin are formed.

Habitat: Sea water.

Genus V. Rhodothece *Molisch, 1906.*

Cells usually spherical and in pairs, each surrounded by a spherical or elliptical capsule. Non-motile. Cells not united into families. Cells contain bacteriopurpurin and sulfur granules.

The type species is *Rhodothece pendens* Molisch.

1. **Rhodothece pendens** Molisch. (Die Purpurbakterien, Jena, 1907, 17.) Spherical organisms, 1.8 to 2.3 microns in size. Encapsulated. The cells contain a few red motile granules and also bacteriopurpurin and bacteriochlorin.

Habitat: Sea water.

Subfamily II. Rhodobacterioideae Buchanan, 1918.

Cells not filamentous, containing bacteriopurpurin but no granules of sulfur.

Synonym: *Athiorhodaceae* Molisch, 1907.

Key to the genera of subfamily **Rhodobacterioideae.**

A. Cells rod-shaped, many embedded in the same slimy capsule.
    Genus I. *Rhodocystis*, p. 579.
B. Cells spherical or short rods.
    1. In chains, each chain surrounded by a capsule.
        Genus II. *Rhodonostoc*, p. 579.
    2. Cells free.
        Genus III. *Rhodorhagus*, p. 580.
C. Cells free and elongate.
    1. Cells not bent.
        a. Non-motile.
            Genus IV. *Rhodobacterium*, p. 580.
        b. Motile.
            Genus V. *Rhodobacillus*, p. 581.
    2. Cells bent or curved.
        a. Cells short, comma-shaped, with single polar flagellum.
            Genus VI. *Rhodovibrio*, p. 581.
        b. Cells spiral, with polar flagella.
            Genus VII. *Rhodospirillum*, p. 581.

Genus I. Rhodocystis *Molisch, 1907.*

Cells rod-shaped, dividing only in one plane, embedded in a common slimy capsule.

The type species is *Rhodocystis gelatinosa* Molisch.

1. **Rhodocystis gelatinosa** Molisch. (Die Purpurbakterien, Jena, 1907, 22.)

Rods with rounded ends, 0.6 by 2.0 to 5.0 microns. Encapsulated. The cells contain bacteriopurpurin and bacteriochlorin.

Habitat: River water.

Genus II. Rhodonostoc *Molisch, 1907.*

Cells spherical or short rods, in rosary-like chains, and embedded in a common gelatinous capsule.

The type species is *Rhodonostoc capsulatum* Molisch.

1. **Rhodonostoc capsulatum** Molisch. (Die Purpurbakterien, Jena, 1907, 22.)

Spheres, 1.4 to 2.0 microns in size. Encapsulated. Masses of cells show a brownish-red color, due to the presence of bacteriopurpurin and bacteriochlorin.

Gelatin not liquefied.

Microaerophilic.

Habitat: River water.

Genus III. Rhodorhagus *Bergey et al., 1925.*[1]

Cells spherical, non-motile, free, not united into families.

The type species is *Rhodorhagus capsulatus* (Molisch) Bergey et al.

1. **Rhodorhagus capsulatus** (Molisch) Bergey et al. (*Rhodococcus capsulatus* Molisch, Die Purpurbakterien, 1907, 20; *Rhodosphaera capsulata* Buchanan, Jour. Bact., *3*, 1918, 472; Bergey et al., Manual, 2nd ed., 1925, 414.)

Spheres 1.5 to 1.8 microns in size. Encapsulated. The cells contain bacteriopurpurin and bacteriochlorin.

Habitat: River water (Moldau).

2. **Rhodorhagus minor** (Molisch) Bergey et al. (*Rhodococcus minor* Molisch, Die Purpurbakterien, Jena, 1907, 21; *Rhodosphaera minor* Bergey et al., Manual, 1st ed., 1923, 406; Bergey et al., Manual, 2nd ed., 1925, 415.)

Spheres 0.8 to 1.2 microns in size, without capsule. Cells contain bacteriopurpurin and bacteriochlorin.

Habitat: River water (Moldau).

Genus IV. Rhodobacterium *Molisch, 1907.*

Rod-shaped cells, non-motile, not united into families.

The type species is *Rhodobacterium capsulatum* Molisch.

1. **Rhodobacterium capsulatum** Molisch. (Molisch, Die Purpurbakterien, 1907, 16.)

Short rods, 0.9 by 1.8 microns, sometimes almost spherical. Encapsulated. Non-motile. Masses of cells are deep, carmine-red, due to the formation in the plasma of bacteriopurpurin and bacteriochlorin.

Agar colonies: One to two millimeters in diameter, pale red. Deep colonies small, deep red.

Gelatin stab: At first pale red, becoming deep red. No liquefaction.

Agar slant: Pale red surface growth. Filiform growth in stab.

Potato: Deep carmine-red streak.

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[1] *Note:* The generic name *Rhodosphaera* used in the first edition of the Manual is invalid because of prior use for a genus of flowering plants.

Aerobic.
Optimum temperature 25° to 37°C.
Habitat: Sea water.

Genus V. Rhodobacillus *Molisch, 1907.*

Rod-shaped cells, solitary, usually motile.
The type species is *Rhodobacillus palustris* Molisch.

1. **Rhodobacillus palustris** Molisch. (Molisch, Die Purpurbakterien, 1907, 14.)

Short rods, 0.5 by 1.5 to 2.5 microns, with rounded ends, occurring singly, rarely two to four end to end. Motile in fluid media. Individual cells colorless; masses show deep, carmine red. The organism contains bacteriopurpurin and bacteriochlorin.

Agar colonies: In one to two months the surface colonies are soft, glistening, at first whitish, becoming red in the center. The deep colonies are lenticular or circular, deep red.

Gelatin stab: At first whitish, becoming pale red, moist, glistening entire. Little growth in stab. No liquefaction.

Broth: Turbid, with red sediment.

Potato: Red, soft, glistening, spreading.

Aerobic.

Optimum temperature 25° to 40°C.

Habitat: In swamps and streams.

Genus VI. Rhodovibrio *Molisch, 1907.*

Cells short, comma shaped, free, actively motile with a polar flagellum.
The type species is *Rhodovibrio parvus* Molisch.

1. **Rhodovibrio parvus** Molisch. (Molisch, Die Purpurbakterien, 1907, 21.)

Slightly curved rods, 0.9 by 1.6 to 2.1 microns. Motile with a long polar flagellum. Masses of cells show a red color.

Microaerophilic.

Habitat: Water.

Genus VII. Rhodospirillum *Molisch, 1907.*

Cells spiral, actively motile by means of polar flagella.
The type species is *Rhodospirillum rubrum* (Esmarch) Molisch.

1. **Rhodospirillum rubrum** (Esmarch) Molisch. (*Spirillum rubrum* Esmarch, Cent. f. Bakt., *1*, 1887, 225; Molisch, Die Purpurbakterien, 1907, 25.)

Spiral forms, 0.6 by 1.5 to 2.5 microns, with one to three turns. Cells contain bacteriopurpurin and bacteriochlorin. Motile.

Gelatin colonies: Small, slightly granular, entire, gray, becoming bluish-red to wine-red color.

Gelatin stab: Colorless growth on surface. Red growth in stab. No liquefaction.

Agar slant: Gray surface growth, becoming pink.

Potato: Deep red growth.

Aerobic, facultative.

Optimum temperature 37°C.

Habitat: Isolated from putrefying blood of mouse.

2. **Rhodospirillum photometricum** Molisch. (Die Purpurbakterien, Jena, 1907, 24.)

Spiral forms, 1.4 by 5 to 8 microns, usually S-shaped, with a flagellum at each end. Actively motile. The cells contain bacteriopurpurin and bacteriochlorin.

Microaerophilic.

Habitat: River water (Moldau).

3. **Rhodospirillum giganteum** Molisch. (Die Purpurbakterien, Jena, 1907, 24.)

Spiral forms, 1.2 by 14 to 20 microns, with one to six turns. Cells contain bacteriopurpurin and bacteriochlorin. Has not been isolated in pure culture.

Habitat: River water (Moldau).

FAMILY II. BEGGIATOACEAE MIGULA, 1900.

Filamentous bacteria, usually showing an oscillating motion similar to Oscillatoria. Cells contain sulfur granules. Spore formation and conidia unknown.

Key to the genera of family **Beggiatoaceae.**

A. Filaments non-motile, with a contrast to base and tip; attached.
Genus I. *Thiothrix*, p. 582.

B. Filaments motile (oscillating) not attached, no differentiation into base and tip.
  1. Filaments not in bundles nor surrounded by a gelatinous sheath,
  Genus II. *Beggiatoa*, p. 583.
  2. Filaments in bundles, surrounded by a gelatinous sheath.
  Genus III. *Thioploca*, p. 584.

Genus I. **Thiothrix** *Winogradsky, 1888.*

Filaments non-motile, segmented, with a definite differentiation into base and tip, attached, usually filled with sulfur granules. The threads produce rod-shaped conidia at the ends. These conidia are motile, exhibiting a slow, creeping movement, attach themselves and develop into threads. The habitat is hot sulfur springs.

The type species is *Thiothrix nivea* (Rabenhorst) Winogradsky.

1. **Thiothrix nivea** (Rabenhorst) Winogradsky. (*Beggiatoa nivea* Rabenhorst, Flora europea algarum, II, 94; *Leptotrichia nivea* De Toni and Trevisan, Saccardo, Syll. Fung. *7*, 1889, 934; Winogradsky, Beiträge zur Morph. u. Physiol. der Bakterien, I. Schwefelbakterien, 1888, 39.)

Filaments with a thin sheath, 2.0 to 2.5 microns broad at the base, and 1.4 to 1.5 microns broad at the apex, often 100 microns long, segmented at the apex, producing motile conidia 8 to 9 microns long.

Habitat: In sulfur and stagnant water.

2. **Thiothrix tenuis** Winogradsky. (Beiträge zur Morph. u. Physiol. der Bakterien, I. Schwefelbakterien, 1888, 39.)

Filaments very long and about one micron in thickness; of nearly uniform thickness.

Habitat: Sulfur water.

3. **Thiothrix tenuissima** Winogradsky. (Beiträge zur Morph. u. Physiol. der Bakterien, I. Schwefelbakterien, 1888, 39.)

Filaments not exceeding 0.5 microns in thickness, forming very close aggregations.

Habitat: Sulfur water.

4. **Thiothrix annulata** Molisch. (Cent. f. Bakt., II Abt., *33*, 1912, 58.)

Thickness of threads: 2 microns at base, 3.4 microns in the middle and 1.8 microns at the top. In the parts thickened in the form of knots, the thickness may reach 5 microns. Length of threads, up to 5 microns. Height of cells is about 1 micron.

Habitat: Sea water and algal infusion.

5. **Thiothrix marina** Molisch. (Cent. f. Bakt., II Abt., *33*, 1912, 58.)

Thickness, 0.8 to 1.3 microns. Length usually 130–300 microns, less frequently 500 microns. Threads often in bunches, each one with a small adhering disc.

Habitat: Sea water containing rotting algae.

Genus II. Beggiatoa *Trevisan, 1842.*

Threads sheathless, formed of flat, discoidal cells, not attached. Multiplication by transverse splitting of the threads. Show undulatory creeping. Cells contain granules of sulfur.

The type species is *Beggiatoa alba* (Vaucher) Trevisan.

1. **Beggiatoa alba** (Vaucher) Trevisan. (*Oscillaria alba* Vaucher, Conferv., 198; *Beggiatoa punctata* Trevisan, Flora Euganea, 1842, 56; See Trevisan, I Generi e le Specie delle Batteriacee, 1889, 10.)

Filaments of considerable length and 3 to 4 microns in thickness, containing numerous strongly refracting granules of sulfur. The filaments break up into short segments which then grow out into longer threads. Sulfates reduced to free sulfur. The filaments are attached to aquatic plants producing slimy flakes.

Habitat: Sulfur springs; swamps.

2. **Beggiatoa roseopersicina** (Cohn) Zopf. (*Clathrocystis roseo-persicina* Cohn, Beiträge z. Biol. d. Pflanzen, *1*, Heft III, 1875, 157; Zopf, Die Spaltpilze, 1885, 102.)

Filaments of about the same dimensions as *Beggiatoa alba*, but of a red-violet color.

Habitat: Stagnant water, forming a red-violet surface growth.

3. **Beggiatoa arachnoides** (Agardh) Rabenhorst. (*Oscillaria arachnoidea*, Agardh, Regensburger Flora, 1827, 634; Rabenhorst, Flora europea algarum, *2*, 1865, 94.)

Filaments 7 microns in thickness.

Habitat: Swamps and sulfur springs.

4. **Beggiatoa mirabilis** Cohn. (Hedwigia, 1865, 81.)

Filaments 16 microns in thickness, occurring as a white growth on dead algae.

Habitat: Sea water.

5. **Beggiatoa leptomitiformis** (Meneghini) Trevisan. (Meneghini, Ragazz, Nuove richerche fisico-chemico, 122; Trevisan, Flora Euganea, 1842, 56.)

Filaments without definite segmentation, very thin, 1.8 to 2.5 microns, forming a thin, white, chalky sediment.

Habitat: Sulfur springs, swamps and sewers.

6. **Beggiatoa minima** Warming. (Om nogle ved Danmarks Kyster levende Bakterier, 356.)

Filaments resemble *Beggiatoa leptomitiformis*, but are definitely segmented, 1.8 to 2.0 microns in thickness forming threads up to 40 microns long.

Habitat: Sea water.

7. **Beggiatoa marina** Molisch. (Cent. f. Bakt., II Abt., *33*, 1912, 59.)

Filaments 2–4 microns in thickness and up to 2000 microns, usually 290-350 microns in length.

Habitat: Sea water, in infusion of rotting algae.

Genus III. **Thioploca** *Lauterborn, 1907.*

Filaments *Beggiatoa*-like, with numerous sulfur granules, motile, lying parallel in considerable numbers, or united in bundles enclosed in a colorless layer of gelatin.

The type species is *Thioploca schmidlei* Lauterborn.

1. **Thioploca schmidlei** Lauterborn. (Ber. d. deutschen botan. Gesellschaft, *25*, 1907, 238.)

Filaments, 5.9 microns thick, enclosed in a gelatinous sheath 50 to 160 microns thick.

Habitat: Found on the bed of the ocean.

FAMILY III. ACHROMATIACEAE BUCHANAN, 1918.

Unicellular, large, motile (by means of flagella?). Cells containing granules of sulfur (or in one form possibly oxalate), but no bacteriopurpurin.

Key to the genera of family **Achromatiaceae.**

A. Cells spherical or ellipsoidal.
   1. Cells ellipsoidal (spherical when newly divided). Cells containing granules of calcium oxalate (perhaps sulfur).
      Genus 1. *Achromatium*, p. 585.
   2. Cells spherical with sulfur granules in a central vacuole.
      Genus 2. *Thiophysa*, p. 586.

B. Cells spiral.
      Genus 3. *Thiospira*, p. 586.

C. Cells longer, very large (42 to 86 microns), with peritrichous flagella.
      Genus 4. *Hillhousia*, p. 587.

Genus I. **Achromatium** *Schewiakoff, 1893.*

Cells large, nearly spherical (in newly divided cells), to ellipsoidal, 9 to 22 by 15 to 43 microns. Cells closely packed with large granules, at first interpreted as sulfur, but later as calcium oxalate. When granules are dissolved, cells show a coarse structure. Cells are motile. Cell division resembles the constriction of flagellates rather than the fission characteristics of bacteria.

The type species is *Achromatium oxaliferum* Schewiakoff.

1. **Achromatium oxaliferum** Schewiakoff. (Ueber einer neuen bakterienähnlichen Organismus des süswassers, Heidelberg, 1893.)

Cylindrical, with rounded ends, 9 to 22 by 15 to 43 microns. Division occurs by indentation at right angles. Slightly motile, with slow, backward movement, undulatory and at times rotary. No flagella have been demonstrated. A number of large refractile granules which contain calcium and oxalic acid. The oxalate is found in the protoplasts. Sulfur granules are in the walls of the protoplasts.

Habitat: The organism occurs in the slime at the bottom of rivers in the so-called "Modder."

2. **Achromatium mulleri** (Warming) Migula. (*Monas mulleri* Warming, Om nogle ved Danmarks Kyster levende Bakterier, Kjöbenhavn, 1876; Migula, System der Bakterien, 1900, 1038.)

Spherical, elliptical or ovoid cells 5.6 to 15 microns in diameter. At times they are filled with granules and appear quite dark, namely the ends are clear and the remainder of the cell very dark with refractile granules. Motile with polar flagella. Division claimed to be longitudinal. Red coloring matter absent.

Habitat: Sea water.

Genus II. Thiophysa *Hinze, 1903.*

Spherical cells, the cell membrane of which is loaded with sulfur granules. The protoplasmic layer surrounds a large central vacuole. The oxalate is contained in the vacuole. Cell nucleus not recognized. Flagella lacking. Cells elongate before division, divide into biscuit-shaped cells. Cells 7 to 18 microns in diameter.

In the presence of an excess of oxygen the sulfur drops disappear and only the oxalate remains. With a lack of oxygen, in the presence of H_2S, the oxalate disappears and sulfur drops fill the cell.

The type species is *Thiophysa volutans* Hinze.

1. **Thiophysa volutans** Hinze. (Ber. der deut. botan. Gesellsch., *21*, 1903, 309.)

Spherical cells 7 to 18 microns in diameter. Show slow, circular motion.

Habitat: In fine sand, Gulf of Naples.

2. **Thiophysa macrophysa** Nadson. (Jour. de Microbiologie (Russian), *1*, 1914, 52.)

21 to 40 microns in diameter (22 to 26 microns most often). Motile spherical cells; no flagella.

Genus III. Thiospira *Vislouch, 1914.*

Colorless, motile, slightly bent, somewhat pointed at the ends, with granules of sulfur within the cells and a small number of flagella at the ends.

The type species is *Thiospira winogradskyi* (Omelianski) Vislouch.

1. **Thiospira winogradskyi** (Omelianski) Vislouch. (*Thiospirillum winogradskyi* Omelianski, Cent. f. Bakt., II Abt., *14*, 1905, 769; *Thiospirillum granulatum* Molisch, Cent. f. Bakt., II Abt. *33*, 1912, 55; Vislouch, Jour. de Microbiologie (Russian) *1*, 1914, 50.)

Large, sulfur spirilla, somewhat pointed at the ends, 2 to 2.5 microns thick, to 50 microns long. Numerous granules of sulfur. Very motile, with one to two polar flagella.

Habitat: Curative mud.

2. **Thiospira bipunctata** (Molisch) Vislouch. (*Spirillum bipunctatum* Molisch, Cent. f. Bakt., II Abt., *33*, 1912, 55; Vislouch, Jour. de Microbiologie (Russian) *1*, 1914, 50.)

Small, slightly bent sulfur spirilla, markedly pointed at the end, 6.6 by 14 microns long, 1.7 to 2.4 microns wide (in the center of the cell). Both ends are filled more or less with large volutin (metachromatic) granules. Several minute granules of sulfur are present in the clear center and sometimes at the ends. Old cells possess one flagellum at each end; young cells have a flagellum at one end.

Habitat: Sea and salt waters.

Genus IV. **Hillhousia** *West and Griffith, 1909.*

Cells very large, 20 to 33 by 42 to 86 microns. Motile by means of peritrichous flagella. Cells packed with large globules of oily, amorphous sulfur.

The type species is *Hillhousia mirabilis* West and Griffith.

1. **Hillhousia mirabilis** West and Griffith. (Proc. Royal Society, Biological Sciences, *181*, 1909, 398.)

Rods, 26 by 60 microns. Motile with short, peritrichous flagella. The cell wall is lamellar. The cytoplasm presents a definite network in the meshes of which are large sulfur granules. Fission proceeds slowly, usually requiring 24 hours or longer.

Habitat: Decomposing organic materials.

ORDER V. MYXOBACTERIALES* JAHN, 1911.

Synonymy: *Myxobacteriaeeae* Thaxter, Bot. Gaz., *17*, 1892, 389; *Myxobactrales* Clements, The genera of fungi, Minneapolis, 1909; *Synbacteries* Pinoy, C. R. Acad. Sci., Paris, *157*, 1913, 77; *Myxobactericeae* Heller, Jour. Bact., *6*, 1921, 521; *Polyangidae* Jahn, Beiträge zur botanischen Protistologie, I, Die Polyangiden, Geb. Borntraeger, Leipzig, 1924.**

The name *Myxobacteriaceae*, although having the form of a family designation, was proposed by Thaxter (1892 *loc. cit.*) in an article bearing the title "On the *Myxobacteriaceae*, a new order of *Schizomycetes.*" Apparently the first ordinal name was that given by Clements (1909 *loc. cit.*), but does not follow the spelling fixed by the precedent of Thaxter. The correct spelling was given by Jahn (Kryptogamenflora der mark Brandenburg, V, Pilze 1, Lief. 2, 1911, 201.) as *Myxobacteriales.* Pinoy (C. R. Acad. Sci. Paris, *157*, 1913, 77) suggested *Synbacteriès.* The name *Myxobacterieae* was proposed by Heller (Jour. Bact., *6*, 1921, 521) as a class designation, *Bacteria* being regarded as the designation of a phylum. *Polyangidae* is likewise a class designation, Jahn (1924 *loc. cit.*) concluding this group should be coordinate in rank with the *Schizomycetes.* Buchanan (Jour. Bac., *3*, 1918, 541) proposed the name *Myxobacteriales*, not knowing of the previous use of the term. He has therefore at times been incorrectly designated as the author of the name.

It may be argued that a more appropriate ordinal designation might be *Polyangiales*, inasmuch as the generic name *Myxobacter* proposed by Thaxter was soon found to be a synonym of *Polyangium* Link. However, there would seem to be justification of the retention of a name based upon an "ancient generic name" in Rule 21 of the Brussels Code.

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* The section covering the Order *Myxobacteriales* has been prepared by Dr. R. E. Buchanan, Ames, Iowa.

** The monograph on *Polyangidae* by Jahn is the most complete discussion of morphology, physiology, and classification of this group. It has been consulted freely in the preparation of this revision.

The group is herein regarded as an order. There do not seem to have been presented by Jahn adequate reasons for making it a class.

Common or trivial names. The slime bacteria, myxobacteria or polyangids.

Brief characterization of the order. The cells develop as a colony (pseudoplasmodium or swarm) consisting of slender, relatively flexible elongate rods. The cells move together as an advancing mass by the excretion of a slime. No flagella. The fruiting bodies may consist of numerous spores which develop by a shortening of the rods, or of cysts in the interior of which lie more or less shortened rods. Fruiting bodies various, sometimes sessile, frequently stalked. Usually colored, frequently yellow or red.

Usually cultivated on dung media. Most species found on dung, or isolated from soil. One species aquatic, parasitic on *Cladophora*.

Culture Media. The myxobacteria may frequently be cultured by transferring to the medium on which they are found to grow in the wild state, usually dung. Sterilized dung is not as favorable in some cases as the unsterilized. Dung agar, particularly that made by addition of 2 per cent agar to rabbit dung decoction is frequently useful. Quehl (Cent. f. Bakt., II Abt., *16*, 1906, 9.) used malt extract + 15 per cent gelatin, and secured slow growth at 18° to 20°C. with some forms, with gradual digestion. A potato nutrient agar is frequently satisfactory, even better than dung agar, though no growth occurs on sterile potato. In media peptone is necessary. Dextrose apparently has little affect. Pinoy (C. R. Acad. Sci. Paris, *157*, 1913, 77.) claims that satisfactory cultures of *Chondromyces crocatus* can be secured only on a medium on which a coccus related to *Micrococcus luteus* is growing. Kofler (Sitzber d. Kais. Akad. Wiss. Wien. Math.— Nat. Klasse, 122 Abt., 1913, 845.) used successfully a medium containing 15 g. sucrose, 2.5 g. peptone, 0.25 g. $MgSO_4$, 0.25 g. KH_2PO_4, 9 g. agar and 500 cc. water. Growth was also obtained on Hasting's casein agar and on dung extract agar. He also used successfully a liquid dung extract.

Temperature range. Most species cultivated in the laboratory show a minimum between 17 and 20° though some species grow even at 10°. Maximum growth usually occurs at about 35°, and the maximum growth temperature is about 40°. More normal fruiting bodies are produced at lower temperatures.

Krzemieniewski (Acta Soc. Bot. Vol., *5*, 1927, 102.) reports that the fruiting bodies of *Melittangium boletus*, *Myxococcus virescens*, *Chondrococcus coralloides*, *Archangium gephyra* and *Archangium primigenium* var. *assurgens* first develop, followed by *Polyangium fuscum* and *P. fuscum* var. *velatum*. At 30°C. they appear in about 5 to 7 days, at 17° to 20° in 8 to 12 days, and at 11° to 14° in 24 to 30 days. Each 10° rise in temperature approximately halves the time. Other species are slower in developing.

The vegetative rods. The rods are markedly elongate, often 30 times as long as broad. Thaxter noted rods as long as 15 microns. They may be

somewhat pointed, rarely somewhat spindle-shaped, often cylindrical. Thaxter (Bot. Gaz., *37*, 1904, 405) believed a highly elastic wall present, other authors have failed to show it by plasmolytic agents. The cells are flexible, not stiff as are ordinary bacteria. Jahn (1924 *loc. cit.*) states that tinctorial and chemical methods fail to definitely show presence of a membrane, but he believes the elasticity of the cells shows this clearly. Thaxter noted granules within cells, and the presence of nucleus-like granules in the spore of *Myxococcus*. Vaur (Arch. f. Protistenkunde, *5*, 1905, 92.) reported that in germination of the spore of *Myxococcus* a refractive granule is found at each end of the cell. It is stated by Badian (Acta Soc. Bot. Pol., *7*, 1930, 55.) that the cell of *Myxococcus virescens* lacks a true nucleus, but that there is present a structure, basophilic in staining properties, that may be interpreted as nuclear in nature. It is dumb-bell shaped and in mitosis divides longitudinally. In spore formation an autogamy occurs followed by what appears to be a reduction division. He found that the chromatic material was gram-negative at all stages except during the reduction. It may be stained by hematoxylin. Vahle found in rods after 3 or 4 days glistening fat globules, and occasionally, small volutin granules. Glycogen was not found.

In masses the vegetative rods are definitely reddish. Thaxter suggested the possibility that the color might be bacteriopurpurin. Treated with concentrated sulphuric acid it turns blue, hence Jahn (1924 *loc. cit.*) concludes it to be a carotin. The cells multiply by transverse fission. They never occur in chains, but are always single.

Motility of the cells. Baur (1904 *loc. cit.*) states that cells have a power of forward movement at a rate about 10 microns per minute. No flagella are present. The cells do not "swim." They may bend, and are unlike most true bacteria in this respect, though Dobell (Quart. Jour. of Microscop. Science, *56*, 1911, 395, and Arch. f. Protistenkunde, *26*, 1912, 117) describes such flexibility for the giant bacteria (See *Bacillus flexilis*). This is characteristic also of *Beggiatoa*, *Oscillatoria* and *Spirochaeta*.

The cells *en masse* move in a "front," advancing and leaving behind a slime. The cells in general tend to lie on rather than in the slime. The exact mechanism of motion has proved puzzling. Jahn believes the motion to be related to that of forms like *Oscillatoria*, and to be due to excretion of slime from the cell, probably an asymmetrical excretion which pushes the cell along.

Swarm stage or pseudoplasmodium. The colony of bacteria with the accompanying slime bears a superficial resemblance to the plasmodium of the slime molds (*Myxomycetes*). It differs, however, in that in the latter the plasmodium is made up of the fused bodies of large numbers of amoeboid cells. In the *Myxobacteria* the cells are bacterial rods, not amebae, and the slime is not protoplasmic. The colony as a whole appears to be amoeboid due to the advancing front of bacteria. The colony is certainly not a true plasmodium. The bacteria are marginal in the colony, and the fruiting bodies tend to be found in concentric rings in consequence.

Thaxter proposed the term pseudoplasmodium as a satisfactory name for the vegetative colony. Jahn regards the name as unsuited and prefers the use of "swarm stage."

The fruiting bodies. After growth as a vegetative colony the pseudoplasmodium forms fruiting bodies of many shapes and sizes. Differentiation of species, genera and families is almost entirely upon the character of fruiting body developed. In some cases a stalk is produced, in some not.

In some forms the stalk is delicate and white, consisting of little changed slime, in other cases it may be stiff and colored. The rods evidently are carried up by the slime which they secrete. In some forms the stalk is simple and short, in others relatively long and branched.

The rods ordinarily associate in more or less definite clumps to form cysts. These cysts may be sessile or stalked. Usually the rods shorten and thicken materially before the cyst ripens. In some forms they shorten so much as to become short ovoid or cylindrical, functioning as spores. They are not endospores such as are found in the genus *Bacillus*.

The cysts may or may not possess a definite membrane produced from slime. Usually the cysts are bright colored, frequently red, orange or yellow. The spores within the cysts when dried retain their vitality for considerable periods of time. Jahn records germination of *Polyangium fuscum* after $5\frac{3}{4}$ years, of *Myxococcus fulvus* after 8 years.

Cultivation of organisms. Pure cultures of various species have been grown upon various media, and substrates, such as dung, dung extract agar, nutrient agar, potato agar, lichens. Apparently, little study has been made of the exact food requirements and the physiology is not well understood. Studies on this phase are needed. Some species have not been cultivated, or have failed to fruit on artificial media in pure cultures. The Krzemieniewskis' (1927 *loc. cit.*) showed that the optimum hydrogen ion concentrations for growth of different species were found between the pH limits of 3.6 and 8.0.

Relationships of the Myxobacteria. The resemblance of the pseudoplasmodium of the myxobacteria to the plasmodium of the slime molds is as noted above probably to be regarded as without significance, as is also the superficial resemblances of the fruiting bodies of the two groups. Jahn (1924) dismisses the relationship to the *Thiobacteriales* suggested by Thaxter as improbable. Thaxter believed the possession of the red color might show presence of bacteriopurpurin. The "carotin" reaction found by Jahn he believed would argue against it. However, it should be more carefully investigated. Jahn insists upon close relationships to the blue-green algae, particularly because of the mobility of the cells and the creeping motion. He does not believe all *Schizophytes* that do not belong to the *Cyanophyceae* (blue green algae) should be grouped as bacteria. He believes the myxobacteria to be more closely related to the blue green algae than to the true bacteria, and creates the class *Polyangidae* to be coordinate with the class *Schizomycetes*. In this he ignores the equal evidence of close relationship of the sulphur bacteria to the *Cyanophyceae*.

His argument would lead to the recognition of all the orders of bacteria recognized in this manual as Classes. The wisdom of this is not apparent. The *Myxobacteriales* may be regarded as a well differentiated order of the *Schizomycetes* resembling the true bacteria on the one hand and the *Myxophyceae* (*Cyanophyceae*) and *Thiobacteriales* on the other.

Habitat. Most of the species have been described from dung. The work of the Krzemieniewskis' (1927 *loc. cit.*) seems to indicate that they occur commonly in soils, and are probably normal constituents of the soil flora. Different species were characteristic of different soils. Soil acidity was found to be particularly significant in determining species present. The technique of isolation was to sieve 100–150 gm. of fresh soil; this was placed on blotting paper in large Petri dishes, and 120–150 pellets of sterilized rabbit dung placed on the surface. Water was added to 70 to 100 per cent saturation, and the plates incubated at 26° to 30°C. The fruiting bodies were found in 5 to 10 days. Altogether 23 species and one variety were thus found, the most common being *Archangium gephyra*.

The distribution of myxobacteria in the soil is closely related to the hydrogen ion concentration, some species are found only in alkaline or neutral soils (pH = 6.0 to 8.0), others in neutral or weekly alkaline soils (pH = 5.0 to 8.0), others only in acid soils (pH = 3.6 to 6.4), some species showed a wide tolerance (pH = 3.6 to 8.0).

Krzemieniewski (1927) also reported that soils from the mountains contained fewer myxobacteria than soils from the lowlands.

Geitler (1924) has found one aquatic species, parasitic on *Cladophora*.

Key to the families of the order **Myxobacteriales.**

(Adapted from Jahn)

1. In fruiting bodies the rods may be more or less shortened, but never rounded as cocci.
   - A. Colonies (swarms) do not form rounded cysts, but heap up either to form mesenteric masses or to produce finger-like or columnar bodies.

     Family I. *Archangiaceae*, p. 591.
   - B. Swarms produce cysts of definite shape.
     - a. Cysts are angular.

       Family II. *Sorangiaceae*, p. 596.
     - aa. Cysts are rounded.

       Family III. *Polyangiaceae*, p. 599.
2. In fruiting bodies the rods are shortened to form rounded spores (cocci).

   Family IV. *Myxococcaceae*, p. 611.

FAMILY I. ARCHANGIACEAE JAHN 1924.

In the organisms belonging to this family the swarm (pseudoplasmodium) produces irregular swollen or twisted fruiting bodies, or develops columnar or finger-like growths usually without a definitely differentiated membrane.

Key to the genera of family **Archangiaceae.**

1. Fruiting body depressed, usually irregularly delimited, the interior usually consisting of swollen or intestine-like twisted or intertwined masses, whose windings may be constricted or may jut out (project) as free ends.

   Genus I. *Archangium*, p. 592.
2. Fruiting body consists of single (separate) columnar or finger-like structures arising from the substrate.

   Genus II. *Stelangium*, p. 595.

Genus I. **Archangium** *Jahn 1924.*

Etymology. Greek (nouns) primitive and vessel, (according to Jahn, this genus is the most primitive).

The mass of shortened rods embedded in slime form a pad-shaped or more rounded, superficially swollen or tuberous fruiting body, even with horny divisions. The fruiting body has no membrane. In the interior can be seen a mass resembling coiled intestines. The windings of this coil may be uniform, or irregularly jointed, free or stuck together: the ends may be extended and horny. Instead of a membrane there may be loosely enveloping slime.

The type species is *Archangium gephyra* Jahn.

Key to the species of genus **Archangium.**

A. No slimy capsules.
  a. Fruiting body usually wound, irregularly constricted, sometimes swollen and vesicular, appressed.
    b. Fruiting body red.
      c. The shortened rods 2.5 to 3 microns.
        1. *Archangium gephyra.*
      cc. The shortened rods 4 to 6 microns.
        2. *Archangium primigenium.*
    bb. Fruiting body yellow.
        3. *Archangium flavum.*
  aa. Tube usually uniformly thick, loosely wound, often branched.
        4. *Archangium serpens.*
B. Fruiting body consisting of a reddish coiled tube, embedded in yellow slime.
        5. *Archangium thaxteri.*

1. **Archangium gephyra** Jahn. (Beiträge zur botanischen Protistologie. I. Die Polyangiden., Geb. Borntraeger, Leipzig, 1924, 67; *Chondromyces serpens* Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 16.)

Etymology: Greek (noun) = a bridge. So named because a transition form between the *Archangiaceae* and the *Myxococcaceae*.

Swarm stage (pseudoplasmodium): Grows easily in manure decoction, forming a pseudoplasmodium and ring of fruiting bodies. The vegetative rods are about 10 microns long, 0.5 microns in diameter.

Fruiting bodies: Up to 1 mm. in diameter, of irregular form and with swollen or padded surface. Average sized fruiting bodies are a reddish flesh color by reflected light; smaller fruiting bodies, a light rose. On a dark background large fruiting bodies when fresh appear bluish violet. By transmitted light the fruiting bodies appear yellowish to light red. Upon addition of alcohol or when heated in glycerine they lose the color quickly and appear gray and colorless.

The inner structures are for the most part a mesenteric mass of tubes 40 to 60 microns wide, without any membrane, and without any enclosing slime. The convolutions are often pressed together. On the inside of these tubes there appears definitely a septation by straight or slightly arched cross walls which, however, do not always cut entirely through the spore masses from one side of the tube to the other. Upon pressure, the fruiting body breaks up into a number of small fragments about 15 to 30 microns in diameter. Within these fragments the shortened rods lie parallel and in bundles.

The rods in the fruiting bodies are so shortened that they resemble the spores of the *Myxococcaceae*. The spores are 2.5 to 2.8 microns long and about 1.4 microns wide. Often they are somewhat bent so that they appear to be bean shaped. In the smooth, transparent tips of fruiting bodies they stand closely parallel to each other, so that in transmitted light one sees only their cross section and is at first led to believe that he is dealing with one of the *Myxococcaceae*.

Occurrence and habitat: Found frequently in the region of Berlin on the dung of deer, rabbits, and hare, once also on old decaying lichens. Easily overlooked on account of its usual bluish color. According to Krzemieniewski (1927) the most common of myxobacteria in the soils of Poland. Isolated on rabbit dung.

Illustrations: Quehl (1906 *loc. cit.*) Pl. 1, Fig.7. Jahn (1924 *loc. cit.*) Pl. 1, Fig. 5. Fig. 5. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. III, Figs. 25-26.

2. **Archangium primigenium** (Quehl) Jahn. (*Polyangium primigenium* Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 16; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden., Geb. Borntraeger, Leipzig, 1924.)

Etymology: Latin (adj.) = primitive, referring to the simple and primitive character of the fruiting body.

Swarm stage (pseudoplasmodium): In manure decoction cysts germinate readily. Vegetative rods 4 to 8 microns in length.

Fruiting bodies: Up to 1 mm. in diameter, sometimes larger, with irregularly padded swollen surface, when fresh a lively red color which is quite prominent especially against a dark background; when dried, dark red. In transmitted light flesh red to yellowish red. In alcohol and upon heating it is quickly bleached.

In transmitted light one sees that the fruiting body is made up of numerous intestine-like convolutions closely appressed, not however, always

definitely delimited. These tubes usually have a diameter of from 70 to 90 microns, often constricted and attenuated, no membrane is present. The rods in the fruiting bodies are about 4 microns long and 0.8 micron wide. Upon pressure on the fruiting bodies, the rods remain together in small fragments of various sizes.

2a. **Archangium primigenium var. assurgens** Jahn. (Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 69; *Archangium assurgens* Krzemieniewski, Acta Soc. Bot. Poloniae, 1927, 95.)

Size and color of the fruiting body as in the species, likewise the inner structure, size and arrangement of the rods. However, the tubules which together constitute the fruiting bodies are more or less free at their ends and stand up from the substrate. Their diameter is somewhat less (about 45 microns), they are often convoluted so that they many times appear to be constricted (like pearls).

Pronounced races of the species and of the variety are so different in habits that they may be regarded as distinct species. Jahn believes the presence of intermediate strains makes a separation difficult.

Occurrence and habitat: According to Jahn, *A. primigenium* is not particularly common. It is usually found on rabbit dung, sometimes on roe dung. The variety *assurgens* is relatively rare (found three times on rabbit dung) Kofler 1930 on rabbit dung, Vienna. Very rare in Polish soils according to Krzemieniewski (1927).

Illustrations: Quehl, Cent. f. Bakt., II Abt,, *16*, 1906, 16, Pl. 1, Fig. 5; Jahn, Kryptogamenflora d. Mark Brandenburg, V, Pilze I, Lief. 2, 1911, 201, Pl. 1, Fig. 5; Jahn (1924 *loc. cit.*) Pl. 1, Fig. 4, also Fig. G, page 37; Krzemieniewski (1926 *loc. cit.*) Pl. II, Fig. 23. (1927 *loc. cit.*) Pl. IV, Fig. 3. var. *assurgens*, Pl. IV, Fig. 1 and 2.

3. **Archangium flavum** (Kofler) Jahn. (*Polyangium flavum* Kofler, Sitzber. d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse, 122 Abt., 1913, 864; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 71.)

Etymology: Latin adjective = golden or reddish yellow.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: About 0.5 mm. in diameter, yellow, spherical or oval, with humped or padded surface. The mass of cells quite homogeneous, upon pressure under cover glass single sections tend to adhere. No membrane, though the rods are so tightly linked that when cautiously placed under a cover glass the form of the fruiting body is retained. Rods 2 to 4 microns.

Occurrence and habitat: Kofler (1924) on hare dung found in Danube meadows. Reported as frequent in Polish soils by Krzemieniewski (1926, 1927).

Illustrations: Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. II, Fig. 24. (1927), Pl. IV, Fig. 4, 5 and 6.

4. **Archangium serpens** (Thaxter) Jahn. (*Chondromyces serpens* Thaxter, Bot. Gaz., *17*, 1892, 403; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 72.)

Etymology: Latin (part. adj.) = creeping.

Swarm stage (pseudoplasmodium): Rods cylindrical, 5 to 7 x 0.6 microns Cultures on agar develop convoluted form.

Fruiting body: About 1 mm. in diameter, recumbent, consisting of numerous loosely intertwined cysts, confluent in an anastomosing coil, flesh colored, when dry dark red, 50 microns in diameter, bent, occasionally somewhat broadened or constricted, branched.

Occurrence and habitat: Thaxter Bot. Gaz., *17*, 1892, 389. On decaying lichens. Cambridge, Mass.

Illustrations: Thaxter (1892 *loc. cit.*), Pl. 24, Fig. 24.

5. **Archangium thaxteri** Jahn. (Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 71.)

Etymology: Named for Dr. Roland Thaxter.

Swarm stage (pseudoplasmodium): Vegetative stages not observed. Either no germination or prompt cessation of growth on dung extract. May be transferred on dung.

Fruiting body: Usually 0.25 to 0.5 mm. occasionally 0.75 mm. in diameter. Irregularly rounded, superficially sulphur yellow. Upon pressure numerous reddish convoluted tubules are observed embedded in a yellow slime. The average diameter of the tubules is about 50 microns. No membrane surrounds the tubes. They contain the shortened rods. The fruiting body is bleached by alcohol or heat, becoming yellowish. Enveloping slime is variable. In well developed specimens the slime forms a stalk, giving the whole the appearance of a morel. In small specimens the rods are embedded in the slime. The fruiting bodies stand loosely separated on surface of dung, never in large groups. Shortened rods (spores) 3 microns by 0.5 micron, very slender.

Occurrence and habitat: According to Jahn rare, on rabbit dung. Races with well developed stalks even less common.

Illustrations: Jahn, 1924 *loc. cit.*, Pl. 1, Fig. 1 and 2. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, Pl. II, Fig. 27.

Genus II. **Stelangium** *Jahn 1924.*

Etymology: Greek (noun) = pillar or column and vessel.

Diagnosis: Fruiting bodes are columnar or finger like, sometimes forked, without definite stalk, standing upright on the substrate.

Type species, *Stelangium muscorum*, (Thaxter) Jahn.

1. **Stelangium muscorum** (Thaxter) Jahn. (*Chondromyces muscorum* Thaxter, Bot. Gaz., *37*, 1904, 411; Jahn, Kryptogamenflora der Mark Brandenburg. V, Pilze I, Lief. 2, 1911, 205.)

Etymology: Latin "of mosses."

Swarm stage (pseudoplasmodium): Not described.

Fruiting body: Bright yellow-orange, 90 to 300 microns long, 10 to 50 microns wide, without differentiated stalk, simple or rarely furcate, upright, elongate, compact or slender, narrowed at tip. Rods (spores) 4 to 6 by 1 to 1.3 microns.

Occurrence and habitat: Thaxter, 1904 *loc. cit.*, on liverworts on living beech trunks in Indiana.

Illustrations: Thaxter, 1904 *loc. cit.* Pl. 27, Figs. 16–18.

FAMILY II. SORANGIACEAE JAHN 1924.

Etymology: Greek (nouns) = heap and vessel.

Diagnosis: The shortened rods of the fruiting body lie in angular, usually relatively small cysts of definite polygonal shape. Often many of these cysts are surrounded by a common membrane. The primary cyst may be differentiated from the angular or secondary cysts. No stalked forms are known.

Genus I. **Sorangium** *Jahn 1924.*

Etymology: Greek (nouns) = heap and vessel.

Diagnosis: As the family. The cysts are united into rounded fruiting bodies. Five species have been allocated to this genus.

Type species: *Sorangium schroeteri* Jahn.

Key to the species of genus **Sorangium.**

1. Fruiting body shows only angular, spherical or oval small cysts.
   a. Cysts angular.
   b. Fruiting body very small (50 to 80 microns), often irregularly cerebriform; the angular cysts are often incompletely separated from each other and are about 12 microns in diameter.
      1. *Sorangium schroeteri.*
   bb. Fruiting body consisting of numerous very small angular cysts about 6 microns in diameter.
      2. *Sorangium sorediatum.*
   aa. Cysts spherical or oval.
      3. *Sorangium spumosum.*
2. Both primary and secondary cysts are present.
   a. Primary cysts small and numerous, about 20 microns, with definite membrane and few angular secondary cysts.
      4. *Sorangium septatum.*
   aa. Primary cyst very large, with delicate and often indefinite membrane.
      5. *Sorangium compositum.*

1. **Sorangium schroeteri** Jahn. (Beiträge zur botanischen Protistologie. I. Die Polyangiden., Geb. Borntraeger, Leipzig, 1924, 73; Regarded as a synonym of *Sorangium compositum* by Krzemieniewski. Acta Soc. Bot. Poloniae, *5*, 1927, 96.)

Etymology: Named for Julius Schroeter (1837–1894).

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Very small, circular, swollen, often kidney shaped with brain-like convolutions, usually 60 microns (occasionally 120 microns) in diameter, bright orange red. Surrounded by a delicate slime membrane about 0.7 microns thick, apparent only with high magnifications. Divided secondarily into angular cysts, by sutures extending inward which divide the mass regularly into well delimited portions, many angled, usually about 12 microns in diameter, and in other places into areas less well delimited and about 14 microns in diameter. Resembles gelatin which has dried in a sheet and cracked into regular areas. Rods in cysts 5 microns long. Cysts sometimes occur together in large numbers, covering an area to 0.5 mm.

Occurrence and habitat: Found by Jahn (*loc. cit.*) five times on rabbit dung in environs of Berlin.

Illustrations: Jahn (1924 *loc. cit.*) Pl. 2, Fig. 22.

2. **Sorangium sorediatum** (Thaxter) Jahn. (*Polyangium sorediatum* Thaxter, Bot. Gaz., *37*, 1904, 414; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden., Geb. Borntraeger, Leipzig, 1924, 73.)

Etymology: From Greek, heap, probably through the botanical term soredium, one type of reproductive bodies in the lichen, and sorediate, with surface patches like soredia.

Swarm stage (pseudoplasmodium): Rods 0.8 by 3 to 5 microns. Attempts to cultivate have failed.

Fruiting body: Orange red, irregularly lobed, consisting of a compact mass of small angular cysts. Average size of cysts 6 to 7 microns, smallest 3 microns, with thick and sharply defined edges. Rods 3 to 5 by 6 to 8 microns. The Krzemieniewskis' (1927 *loc. cit.* p. 96) have described a variety, *Sorangium sorediatum* var. *macrocystum*, consisting of cysts 6 to 14 by 7 to 16 microns, about twice as large as in the type.

Occurrence and habitat: Reported once by Thaxter (1904 *loc. cit.*) on rabbit dung from South Carolina, Krzemieniewski (1927 *loc. cit.*) common in Polish soils.

Illustrations: Thaxter (1904 *loc. cit.*) Pl. 27, Figs. 22–24. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 9, Pl. 1, Fig. 2. Jahn, Kryptogamen-flora d. Mark Brandenburg, V. Pilze I. Lief. 2, 1911, 202, Fig. 1; Krzemieniewski, Acta Soc. Bot. Pol., 4, 1926, Pl. IV, Figs. 39–41. (1927 *loc. cit.*) Pl. V, Fig. 17, var. *macrocystum* Fig. 18.

3. **Sorangium spumosum** Krzemieniewski. (Helena and Seweryn, Acta Soc. Poloniae, *5*, 1927, 97.)

Etymology: Latin (adj.) = frothy or foamy.

Swarm stage (pseudoplasmodium): Rods 2.6 to 5.2 by 0.7 to 0.9 microns.

Fruiting bodies: Consist of numerous cysts, spherical or oval, not surrounded by a common membrane, but united into bodies embedded in slime. Often in double or single rows. Cyst walls colorless, or slightly brownish, transparent, so that the characteristic arrangement of the rods may be seen within. Cysts 8 to 26 by 7 to 20 microns.

Occurrence or habitat: Krzemieniewski (1927 *loc. cit.*) from Polish soil, isolated on rabbit dung.

Illustrations: Krzemieniewski (1927 *loc. cit.*) Pl. V, Fig. 19.

4. **Sorangium septatum** (Thaxter) Jahn. (*Polyangium septatum* Thaxter, Bot. Gaz., *37*, 1904, 412; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden., Geb. Borntraeger, Leipzig, 1924, 75.)

Etymology: Latin, fenced, *i.e.*, divided by walls.

Swarm stage (pseudoplasmodium): Rods 0.8 to 1 by 3 to 5 microns.

Fruiting bodies: Yellowish-orange, dried, dark orange red, 50 microns to more than 100 microns in diameter, cysts rounded or ovoid, angular or cylindrical, inner portion of the envelope divided into a variable number of secondary cysts. Cysts 18 to 22 by 12 to 22 microns in diameter. Secondary cysts 10 to 12 microns. The Krzemieniewskis' (1927, *loc. cit.* p. 96) recognize a variety, *Sorangium septatum* var. *microcystum* which has secondary cysts with dimensions 4 to 10 by 3 to 8 microns.

Occurrence and habitat: Collected twice (Thaxter, Bot. Gaz., *37*, 1904, 412) on horse dung in Cambridge, Mass. Reported by Krzemieniewski (Acta Soc. Poloniae, 5, 1927) as common in Polish soil.

Illustrations: Thaxter, 1904 *loc. cit.* Pl. 27, Figs. 25–28. Jahn, Kryptogamen-flora d. Mark Brandenburg, V. Pilze I. Lief 2, 1911, 202, Fig. 2, Krzemieniewski, Acta Soc. Bot. Pol., *4*, 1926, Pl. 27, Figs. 27–38; *ibid.*, 1927, Pl. V, Fig. 15, var. *microcystum*, Fig. 16.

5. **Sorangium compositum** (Thaxter) Jahn. (*Polyangium compositum* Thaxter, Bot. Gaz., *37*, 1904, 413; Jahn, Beiträge zur botanische Protistologie. I. Die Polangiden., Geb. Borntraeger, Leipzig, 1924, 74.) *Polyangium sorediatum* Quehl (Cent. f. Bakt., II Abt., *16*, 1906, 17) (not Thaxter).

Etymology: Latin (participial adjective) = compound.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Dull yellowish orange changing to dark red on drying. Rounded, small, 0.5 to 1 mm., usually as a whole or even in larger clumps surrounded by a delicate and evanescent membrane. In large fruiting bodies the cysts are bound together in balls 70 to 90 microns in diameter by a delicate membrane. The balls readily fall apart. Secondary cysts are angular, 7 by 11 microns, surrounded by a delicate orange red membrane, about 0.4 micron in thickness. Length of rods in the cysts 5 microns.

Occurrence and habitat: Thaxter (*loc. cit.*) rabbit dung, South Carolina. Jahn (1904, *loc. cit.*) found it four times on rabbit dung near Berlin, and twice on hare dung in Oberharg. Common in soils of Poland according to Krzemieniewski (Acta, 1927).

Illustrations: Thaxter, 1904 *loc. cit.* Pl. 27, Figs. 29–30. Jahn 1924 *loc. cit.* Pl. I, Fig. 6. Krzemieniewski, Acta Soc. Bot. Pol., *4*, 1926 Pl. III, Figs. 32–36; *ibid.*, 1927, *5*, Pl. IV, Figs. 7, 8, 9, 10, 11, 12; Pl. V, Figs. 13, 14; Pl. VI, Fig. 36.

FAMILY III. POLYANGIACEAE JAHN 1924.

Etymology: Greek, many vessels.

Diagnosis: In the fruiting bodies the more or less shortened rods lie in rounded cysts of definite form. The well defined wall is composed of hardened slime, and is yellow, red or brownish. The cysts may be united by a definitely visible slime membrane, the remnant of the vegetative slime, or they may be tightly appressed and cemented by the scarcely visible remnants of the slime, or they may develop singly or in numbers on a stalk. In the more highly developed forms the stalk branches and carries the cysts at the tips of the branches.

Five genera are recognized, the type genus being *Polyangium*.

Key to the genera of family **Polyangiaceae.**

A. Cysts rounded, not stalked, usually many (one in *P. simplex*) lying loosely in a slime membrane or closely appressed.
Genus I. *Polyangium*, p. 599.

B. Cysts not as in A.
  a. Cysts pointed at the apex, often completely concrescent, and united to large disks or spheres.
  Genus II. *Synangium*, p. 604.
  aa. Cysts free, single or many on a stalk.
    b. Cysts forming a disk, flattened dorsoventrally, like the cap of a *Boletus*, on a white stalk.
    Genus III. *Melittangium*, p. 605.
    bb. Cysts not forming a disk.
      c. Cysts rounded or elongate, single on stalks.
      Genus IV. *Podangium*, p. 606.
      cc. Cysts rounded or elongate or pointed, numerous on the ends of stalks which may be branched.
      Genus V. *Chondromyces*, p. 608.

Genus I. **Polyangium** *Link 1809.*

Synonyms: *Cystobacter* Schroeter, Cohn, Kryptogamenflora v. Schlesien, *3*, 1, 1886, 170; *Myxobacter* Thaxter, Bot. Gaz., *17*, 1892, 403.

Etymology: Greek, many vessels, referring to the numerous cysts.

Diagnosis: Cysts rounded or coiled, surrounded by a well developed membrane, either free or embedded in a second slimy layer. Eleven species are recognized, of which the type is *Polyangium vitellinum* Link.

Key to the species of genus **Polyangium.**

I. Not parasitic on water plants (algae).
  A. Cysts rounded to spherical.
    1. Ripe cysts yellow, reddish yellow, orange or light red, not brown.
      a. Cysts several or numerous and small.
      b. Not closely appressed.

c. Slime envelope transparent white or colorless.

d. Cysts usually 10 to 15. Rods in cysts 3 microns. Cysts 75 to 200 microns.

1. *Polyangium vitellinum.*

dd. Cysts numerous. Rods in cysts 1.3 to 2 microns. Cysts 20 to 80 microns.

2. *Polyangium minus.*

cc. Cyst numerous bright yellow.

3. *Polyangium luteum.*

bb. Closely appressed, without enveloping slime.

4. *Polyangium morula.*

aa. Cysts single.

b. Large, 250 to 400 microns, of reddish yellow color.

5. *Polyangium simplex.*

bb. Smaller, 60 to 30 by 50 to 130 microns. Orange to light red.

6. *Polyangium ochraceum.*

2. Ripe cysts reddish brown to dark brown.

a. Cysts lying free, covered by a more or less definite slime envelope.

7. *Polyangium fuscum.*

aa. Cysts rounded, seated in a stellate arrangement on a slimy substrate.

8. *Polyangium stellatum.*

A. Cysts elongate, coiled.

a. Cyst walls brown red.

9. *Polyangium ferrugineum.*

aa. Cysts bright orange yellow.

10. *Polyangium indivisum.*

II. Aquatic, parasitic on *Cladophora.*

11. *Polyangium parasiticum.*

1. **Polyangium vitellinum** Link. (Mag. der Ges. Naturforschender Freunde zu Berlin, *3*, 1809, 42; *Myxobacter aureus* Thaxter, Bot. Gaz., *17*, 1892, 403.)

Etymology: Latin (adj.) = yolk-like.

Swarm stage (pseudoplasmodium): When rising to form cysts, milky white. Rods large, cylindrical, rounded at either end, 4 to 7 by 0.7 to 0.9 microns.

Fruiting body: Cysts golden yellow, usually relatively spherical, 75 to 150 microns, occasionally 200 microns in diameter, almost always surrounded by a white slimy envelope, about 10 to 15 cysts in a mass. Rods in the cysts about 3 microns in length.

Occurrence and habitat: Thaxter (1892 *loc. cit.*). On very wet wood and bark in swamps. Maine, Belmont. Jahn (1924 *loc. cit.*) states it is not common; on old wood, lying in moist ditches, also on old poplar bark which was kept moist in a dish, also found twice on rabbit dung.

Illustrations: Thaxter 1892 *loc. cit.*, Pl. 25, Figs. 34–36. Zukal, Ber. d. d. Bot. Ges., *15*, 1897, 542, Pl. 27, Figs. 6–10. Jahn, Kryptogamen-flora d. Mark Brandenburg, V. Pilze I. Lief. 2, 1911, 199, Fig. 3. Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden., Geb. Borntraeger, Leipzig, 1924, 77, and Pl. II, Fig. 13.

2. **Polyangium minus** Krzemieniewski. (Acta Soc. Bot. Poloniae, *4*, 1926, 33.)

Etymology: Latin (adj.) = less or small.

Swarm stage (pseudoplasmodium): Vegetative rods 3 to 7 by 0.4 to 0.6 microns.

Fruiting bodies: Cyst masses commonly cover the substrate to an area of 0.5 sq. mm. Cysts are spherical or oval, small, 20 to 80 by 20 to 50 microns, light rose in color, becoming brownish, embedded in a transparent colorless slime. Cyst membrane light colored, relatively thick, 0.5 to 1.0 micron, transparent, revealing the contents. Rods in cyst 3 to 7 by 0.4 to 0.6 microns.

Occurrence and habitat: On rabbit dung sterilized and placed on soil (Poland). Rather rare. Relatively slow in appearance, only after many days.

Illustrations: Krzemieniewski (1926 *loc. cit.*) Pl. IV, Fig. 47–48; Pl. V, Fig. 49.

3. **Polyangium luteum** Krzemieniewski. (Acta Soc. Bot. Poloniae, *5* 1927. 98.)

Etymology. Latin (adj.) = yellow.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Golden yellow, consisting of a few cysts surrounded by a common bright yellow very thick slime wall. The cysts have colorless thin walls. Rods 3.8 to 5.8 by 0.7 to 0.8 microns.

Occurrence and habitat: Isolated from soil on rabbit dung by Krzemieniewski (1927).

Illustration: Krzemieniewski (1927 *loc. cit.*) Pl. V, Fig. 22, 23.

4. **Polyangium morula** Jahn. (Kryptogamenflora der Mark Brandenburg. *5*, Pilze I, 1911, 202.)

Etymology: Latin (noun), diminutive of mulberry, referring to shape of cysts.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Cysts bright yellow, closely packed into a mulberry-shaped sorus; cysts with thick membrane (3 microns), often made polygonal by pressure, 20 to 35 microns, bound together by slime. The whole sorus is 100 to 200 microns broad. Rods in cysts about 3 microns in length. Jahn states he has not studied fresh cysts. In the older cysts the rods are difficult to observe.

Occurrence and habitat: Observed once only by Jahn (1911 *loc. cit.*) on rabbit dung.

Illustration: Jahn (1924 *loc. cit.*) Pl. 2, Fig. 21.

5. **Polyangium simplex** Thaxter. (*Myxobacter simplex* Thaxter, Bot. Gaz., *18*, 1893, 29; Thaxter, Bot. Gaz., *37*, 1904, 414.)

Etymology: Latin (adj.) simple, i.e., not compound.

Swarm stage (pseudoplasmodium): Rods, large, cylindrical, rounded at either end, 4 to 7 by 0.7 to 0.9 microns.

Fruiting bodies: Cysts single, very large, 250 to 400 microns, bright reddish yellow, irregularly rounded. Rods flesh colored in mass. Upon pressure adhering together in sheaves.

Occurrence and habitat: Found by Thaxter (1893 *loc. cit.*) in U. S. A. on very wet wood and bark in swamps.

6. **Polyangium ochraceum** Krzemieniewski. (Acta Soc. Bot. Poloniae, *4*, 1926, 34.)

Etymology: Latin (adj.) = ochraceous.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: The orange to light red fruiting body in form of a single spherical or oval cyst 60 to 30 by 50 to 130 microns, each with a thick yellow-brown membrane. The cyst content often (particularly in the oval cysts) is constricted by the membrane which penetrates deeply. From the side the cyst appears to be divided. Rods in cysts 4 to 8 by 0.5 microns.

Occurrence and habitat: From sterilized rabbit dung on soil (Poland).

Illustrations: Krzemieniewski (1926 *loc. cit.*) Pl. V, Fig. 50, 51.

7. **Polyangium fuscum** (Schroeter) Thaxter. (*Cystobacter fuscus* Schroeter, Cohn's Kryptogamenflora v. Schlesien, *3*, 1, 1886, 170; Thaxter, Bot. Gaz., *37*, 1904, 414.)

Etymology: Latin (adj.) fuscous, brown.

Swarm stage (pseudoplasmodium): Rods slender, elongate 0.6 by 5 to 12 microns. Grows readily on agar, also on dung agar. Baur states rods are 15 to 20 microns in length and move about 2 to 3 microns per minute in hanging drop, on agar 5 to 10 microns per minute.

Fruiting bodies: Cysts flesh-colored when young, chestnut brown when ripe, spherical, about 60 microns (Thaxter 50 to 150 by 50 to 70 microns) in diameter, with definite membrane, lying in considerable numbers in large sori, usually 30 to 40 sometimes up to 100. The slime envelope is much more delicate and evanescent than in *P. vitellinum.* Occasionally a form is found with cysts measuring 100 microns: under these often lie kidney shaped cysts even 150 microns in length; apparently, a variety. Rods in cysts about 0.8 to 1.5 by 3 to 3.5 microns. Cysts (Baur) on dung decoction break in 10–12 hours, and rods pour out, apparently passively at first.

P. fuscum var. *velatum* Krzemieniewski differs from the type in that the membrane is thin, separated from cysts, folded.

Occurrence and habitat: Thaxter (Bot. Gaz., 23, 1897), on rabbit dung from southern California. Kofler (Sitzber. d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse., 122 Abt., 1913, 845) on rabbit dung, Vienna. Jahn (Die Polyangiden. Geb. Borntraeg., 1924), common on dung, also occurs on decaying lichens and on poplar bark kept moist. Quite common in Polish soils according to Krzemieniewski (1927 *loc. cit.*).

Illustrations: Thaxter (1897 *loc. cit.*) Pl. 31, Figs. 37–39. Baur, Arch. Protestenkunde, *5*, 1905, Pl. 4, Figs. 14, 15, and 17. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, Pl. 1, Figs. 8 and 16. Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger. Leipzig, 1924, Pl. 2, Fig. 12. Also Fig. A, p. 9. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 34, Pl. IV, Figs. 42–43, also var. *velatum* Plate IV, Figs. 44–46.

8. **Polyangium stellatum** Kofler. (Sitzber. d. Kais. Akad. Wiss. Wien.-Nat. Klasse. *122* Abt., 1913, 19.)

Etymology: Latin (adj.) stellate.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Cysts elongate, 80 to 120 microns broad, 160 to 200 microns long, flesh-colored when young, brownish red when old, star shaped with 2 to 9 rays fixed by the narrowed base upon a kind of hypothallus.

Occurrence and habitat: Found by Kofler (1930 *loc. cit.*) on hare dung at Vienna.

Illustrations: Kofler (1913 *loc. cit.*) Pl. Fig. 6.

9. **Polyangium ferrugineum** Krzemieniewski. (Acta. Soc. Bot. Poloniae, *5*, 1927, 97.)

Etymology: Latin (adj.) = dark red.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Irregular, branched and occasionally constricted coils. Branches of same diameter as the main tube. Cyst wall is brown red. In the interior no differentiation is visible. Rods in cysts are relatively short and thick, 2 to 2.5 microns by 0.8 to 1.1 microns, not definitely arranged. Close to *Archangium gephyra*, but with cyst walls.

Occurrence and Habitat: Krzemieniewski (1927 *loc. cit.*) from soil in Poland on rabbit dung.

Illustrations: Krzemieniewski (1927 *loc. cit.*) Pl. V, Fig. 21.

10. **Polyangium indivisum** Krzemieniewski. (Acta Soc. Bot., Poloniae, *5*, 1927, 97.)

Etymology: Latin (adj.) = undivided.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Similar to *Polyangium ferrugineum*, but much smaller and bright orange yellow. Enclosed in a similarly colored slime membrane. Interior of coils undifferentiated. Cyst rods 3 to 6 by 0.8 to 1.0 microns, straight, and rounded on ends. Arranged perpendicularly to the wall, giving a netted appearance resembling Melittangium.

Occurrence and habitat: From soils in Poland, Krzemieniewski (1927, *loc cit.*)

11. **Polyangium parasiticum** Geitler. (Arch. f. Protistenkunde, *50*, 1924, 67.)

Etymology: Latin (adj.) = parasitic.

Swarm stage (pseudoplasmodium): In water, on surface of the alga Cladophora. Pseudoplasmodia small. Rods long cylindric, rounded at

end and 0.7 by 4 to 7 microns. At first saprophytic, later entering and destroying the Cladophora cell.

Fruiting bodies: Sometimes single, usually 2 to 8, microscopically small, united in irregular masses, spherical or somewhat elongated. From 15 to 50 microns, usually 25 to 40 microns, with hyaline slime. When mature, red brown in color, with firm wall.

Occurrence and habitat: Found on *Cladophora* (*fracta?*) in pool at Vienna (Geitler 1926).

Illustrations: Geitler (1924 *loc. cit.*) Fig. 1–10.

Genus II. **Synangium** *Jahn 1924.*

Etymology: Greek (noun), together and vessel, referring to the clustering of the cysts.

Diagnosis: Cysts provided with an apical point, united more or less completely to rosette-shaped, hemispherical or spherical fruiting bodies. Of the four species described, the first named, *Synangium sessile* (Thaxter) Jahn may be designated as the type.

Key to the species of genus **Synangium.**

A. Cysts irregular, pointed, united as a rosette on a slimy, base, without a stalk.

1. *Synangium sessile.*

B. The fused cysts on a simple or branched stalk.

a. Cyst group spherical, with the points of the cysts covered as with hair, reddish.

2. *Synangium lanuginosum.*

aa. Cyst group an oblate spheroid, yellow. Points of cysts less numerous.

3. *Synangium thaxteri.*

1. **Synangium sessile** (Thaxter) Jahn. (*Chondromyces sessilis* Thaxter, Bot. Gaz., *37*, 1904, 411; Jahn, Beiträge zur botanischen Protistologie. I, Die Polyangiden. Geb. Borntraeger., Leipzig, 1924, *79.*)

Etymology: Latin (adj.) sessile, not stalked.

Swarm stage (pseudoplasmodium): Not described.

Fruiting body: Cysts form on the base a clump or rosette without trace of stalk. Diameter of rosettes 100 to 250 microns. Individually the cysts are quite variable in form, irregularly spindle shaped, usually short pointed, wrinkled surface toward the tip. At the base they fuse or unite to irregular masses. Cysts 18 to 55 by 25 to 75 microns, average 40 by 50 microns.

Occurrence and habitat: Thaxter (1904 *loc. cit.*) found this on decaying wood in Florida.

Illustration: Thaxter (1904 *loc. cit.*) Pl. 27, Figs. 14–15.

2. **Synangium lanuginosum** (Kofler) Jahn. (*Chondromyces lanuginosus* Kofler, Sitzber. d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse. 122 Abt.,

1913, 861; Jahn Beiträge zur botanischen Protistologie. I Polyangiden, Geb. Borntraeger, Leipzig, 1924, 79.)

Etymology: Latin (adj.) woolly.

Swarm stage (pseudoplasmodium): Not described.

Fruiting body: Cyst cluster, consisting of united cysts, spherical or oval, 80 to 200 microns in diameter, when dry dark flesh colored, covered with hairs 15 to 50 microns long, originating from the individual cysts and giving the cyst cluster the appearance of a hairy ball. Skin of the cysts not definite. Rods within the cysts 3 to 6 microns. The cyst clusters are terminal on more or less forked stalks, about 1 mm. high.

Occurrence and habitat: Kofler (1913 *loc. cit.*) found this on rabbit dung at Vienna.

Illustrations: Kofler (1913 *loc. cit.*) Pl. 1, Figs. 1–3.

3. **Synangium thaxteri** (Faull) Jahn. (*Chondromyces thaxteri* Faull, Bot. Gaz., *62*, 1916, 226; Jahn, Beiträge zur botanischen Protistologie, I, Die Polyangiden. Geb. Borntraeger Leipzig, 1924, 79.) Regarded as a synonym of *S. lanuginosum* by Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, 39.

Etymology: Named for Dr. Roland Thaxter.

Swarm stage (pseudoplasmodium): Cultured for 2 years on dung, best in mixed cultures. Rods 0.5 by 3 to 6 microns.

Fruiting body: Fruit cluster flattened, spherical, yellow to flesh color or reddish orange, with a longer or shorter stalk, about 140 microns in diameter. The bristles corresponding to the single cysts are 15 to 30 microns long, at the base 10 to 12 microns wide. Sometimes cyst single, usually 3 to 4, occasionally 20 to 30. Rods 0.5 by 3 to 6 microns. Stalk maximum length 0.75 mm., usually 350 microns, single or branched. Broad based, narrowing to apex and yellow in color. In germination rods move from basal scar of membrane, leaving the empty sack behind.

Occurrence and habitat: On deer dung in Canada, Ontario (Faull).

Illustrations: Faull (1916 *loc. cit.*) Pl. 5 and 6. Jahn (1924 *loc. cit.*) Fig. X, p. 80.

Genus III. **Melittangium** *Jahn 1924.*

Etymology: Greek (nouns) for bee and vessel, because of the honeycomb pattern of the membrane.

Diagnosis: Cysts brownish orange red, on short white stalk, like a mushroom. Has appearance of a white-stalked *Boletus*. The rods inside stand at right angles to the membrane. Upon germination the covering membrane is left colorless and with an appearance of honey comb.

The genus has a single (type) species *Melittangium boletus* Jahn.

1. **Melittangium boletus** Jahn. (Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 78.)

Etymology: Greek (noun) a kind of mushroom.

Swarm stage (pseudoplasmodium): No description.

Fruiting bodies: Cyst stalked, mushroom like, white when immature, then yellowish-flesh colored, finally yellowish brown to nut brown, when dried more reddish brown. Larger diameter of cyst about 100 microns, height 40 to 50 microns, length of white stalk about 40 microns, length of rods in the cyst 3 to 4 microns by 0.5 microns. Sometimes the cyst is smaller and spherical (50 to 60 microns diameter), sometimes there is fusion of neighboring cysts, occasionally the stalk is abortive.

Occurrence and habitat: Jahn (1924 *loc. cit.*) found this not uncommon on rabbit and deer dung in the vicinity of Berlin, also on deer dung from Denmark. Krzemieniewski (1927 *loc. cit.*) reported it as common in Polish soils.

Illustrations: Jahn (1924 *loc. cit.*) Pl. 2, Fig. 17 and 18. Also Fig. B, p. 11, C–F, p. 23, O–Q, p. 43, T–U, p. 55. Krzemieniewski, Acta Soc. Bot. Poloniae, *4*, 1926, 1, Pl. V, Fig. 55–56.

Genus IV. **Podangium** *Jahn 1924.*

Etymology: Greek (noun) foot and vessel.

Diagnosis: Cysts chestnut-brown or red-brown, single on a more or less definite white stalk.

Three species described; of which the first *Podangium erectum* (Schroeter) Jahn may be designated as the type.

Key to the species of genus **Podangium.**

A. Stalk scarcely definite, cysts short, appressed, if elongate then passing over from the white stem into the club-shaped cyst. Ripe cysts chestnut-brown.
   1. *Podangium erectum.*

B. Stalk well differentiated.
   a. Cysts spherical, often irregular, confluent, the white stalk short.
      2. *Podangium lichenicolum.*
   aa. Cysts lengthened ellipsoidal, red brown, definitely differentiated from the white, slender stalks.
      3. *Podangium gracilipes.*

1. **Podangium erectum** (Schroeter) Jahn. (*Cystobacter erectus* Schroeter, Cohn's Krytogamenflora v. Schlesien, *3*, 1, 1886, p. 170; *Chondromyces erectus* Thaxter, Bot. Gaz., *23*, 1897, 407; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger. Leipzig, 1924, 80.)

Etymology: Latin (part. adj.) = erect, upright.

Swarm stage (pseudoplasmodium): Kofler states rods are 2 to 5 microns in length.

Fruiting bodies: Cysts usually short, almost spherical, compact, rounded above, orange red changing to chestnut brown, single on a white to yellow hypothallus constituted from the slime remaining behind. A definite "foot" of whitish slime is seldom observed. Fifty to hundreds together. Usually about 80 microns high and above 40 to 50 microns broad, smaller

below, often spherical cysts 60 microns in diameter. Rods in cysts 0.6 by 4 microns.

Jahn believes the European form to be distinct from that described by Thaxter. Thaxter's form produces cystophores 60 to 300 microns long which wither at maturity so that cysts appear sessile.

Occurrence and habitat: Thaxter (1897 *loc. cit.*), horse dung in laboratory cultures, Massachusetts. Kofler (Sitzber d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse, 122 Abt., 1913), mouse dung. Jahn (1924) common on manure of different kinds, also on bark covered with lichens. Krzemieniewski (Acta Soc. Bot., Pol., *5*, 1927, 102) reported this species from Polish soil, but rare.

Illustrations: Thaxter (1897 *loc. cit.*) Pl. 31, Figs. 16–19. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, Pl. 1, Figs. 4. Jahn (1924 *loc. cit.*) Pl. I, Figs. 7, 8, and 9. Krzemieniewski, Acta Soc. Bot., Poloniae, *4*, 1926, 1, Pl. V, Figs. 52–53.

2. **Podangium lichenicolum** (Thaxter) Jahn. (*Chondromyces lichenicolus* Thaxter, Bot. Gaz., *17*, 1892, 402; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntrager. Leipzig, 1924, 81.)

Etymology: Latin (adj.) = lichen-dwelling.

Swarm stage: Reddish, rods cylindrical, tapering slightly 5 to 7 by 0.6 microns. Germinate readily after drying for 18 months when sown on moist lichens.

Fruiting bodies: Cysts single, rounded or irregularly lobed, often confluent. Cystophore short, squarish, often lacking or misshapen. Cysts 35 to 28 microns, stem 7 to 8 by 10 microns.

Occurrence and habitat: Thaxter (1892). Parasitic upon living lichens, which it destroys. New Haven, Conn. Thaxter (1904 *loc. cit.*), lichens, Indiana, on algae, seen on wet boards, in mill race, Massachusetts.

Illustrations: Thaxter (1892 *loc. cit.*) Pl. 23, Figs. 20 to 23. Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 9, Pl. 1, Fig. 6.

3. **Podangium gracilipes** (Thaxter) Jahn. (*Chondromyces gracilipes* Thaxter, Bot. Gaz., *23*, 1897, 406. Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger. Leipzig, 1924, 82.)

Etymology: Latin = slender foot.

Swarm stage: Rods 5 to 7 microns.

Fruiting bodies: Cysts bright orange-red, or red, 25 by 35 microns, elongate rounded, on a white pointed stalk, rigid and persistent on substratum, rods also in stalk. Shortened rods in cyst 3 to 5 microns. Cysts sometimes pear-shaped, caducous.

Occurrence and habitat: Thaxter (1897 *loc. cit.*) from rabbit dung, Massachusetts. Kofler (1913 *loc. cit.*) dung, Vienna. Jahn (1924 *loc. cit.*) relatively common. Twice on rabbit dung near Berlin, once on goat dung in Norway. Krzemieniewski (1927 *loc. cit.*) reported this species from Polish soil, but rare.

Illustrations: Thaxter (1897 *loc. cit.*) Pl. 31, Figs. 20–24. Quehl, Cent.

f. Bakt., II Abt., *16*, 1906, Pl. 1, Fig. 12. Jahn (1924 *loc. cit.*) Pl. II, Figs. 19, 20. Krzemieniewski (1926 *loc. cit*) Pl. V, Fig. 54.

Genus V. **Chondromyces** *Berkeley and Curtis 1857.*

Synonymy: A species was figured and named in 1857 by Berkeley as *Chondromyces crocatus* Berkeley and Curtis, but not described. The generic name was finally described in 1874. Probably the date of the name should be the date of its description, although it is possible that an adequate labeled illustration should be interpreted as valid publication.

Stigmatella Berkeley and Curtis, 1857, 313 (no description), 1874, 97 (description). Saccardo 1886, 679.

Etymology: Greek (noun) grain and thread (fungus).

Diagnosis: Cysts compactly grouped at the end of a colored stalk (cystophore). Cystophore simple or branched.

Type species *Chondromyces crocatus* Berkeley and Curtis.

Key to the species of genus **Chondromyces.**

A. Cysts not in chains.
  a. Cysts sessile.
  b. Cysts not pointed.
  c. Cysts rounded, yellow.
    1. *Chondromyces crocatus.*
  cc. Cysts rounded, bright orange red.
    2. *Chondromyces aurantiacus.*
  bb. Cysts pointed.
    3. *Chondromyces apiculatus.*
  aa. Cysts stalked at the end of an unbranched cystophore resembling an umbel.
    4. *Chondromyces pediculatus.*
B. Cysts in chains at the end of a compact stalk.
    5. *Chondromyces catenulatus.*

1. **Chondromyces crocatus** Berkeley and Curtis. (Introduction to Cryptogamic Botany, London, 1857, 313; Berkeley, Notes on North American Fungi Grevillea, *3*, 1874, 64; *Myxobotrys variabilis* Zukal, Ber. d. d. bot. Ges., *15*, 1896, 340, according to Krzemieniewski, Acta Soc. Bot., Poloniae, *4*, 1926, 38.)

Etymology: Latin (adj.) = saffron yellow.

Swarm stage (pseudoplasmodium): Pale orange red. Rods cylindrical or tapering slightly, straight or slightly curved, 2.5 to 6 by 0.6 to 0.7 microns. Cultivated on nutrient agar and sterilized horse dung. Cysts placed in moist chamber germinate in one or two days. The contents are first contracted within the cyst walls, showing the individual rods. The cyst wall is then absorbed or disappears at the base, and the rods escape in a regular stream until only the empty cyst is left.

Fruiting bodies: Cysts nearly conical, rounded at tip, average 12 by 28

microns, (6 to 20 by 15 to 45 microns), straw yellow, in spherical heads of variable numbers (70 to 90 microns) at tips of branches. Cystophore orange colored, slender, striated, often twisted or irregularly bent, simple or branched as many as 5 times. About 600 microns high, rarely 1 mm.

Occurrence and habitat: Thaxter (1892 *loc. cit.*), melon rind from South Carolina and old straw from Ceylon, Cambridge, Mass. Zukal (1896 *loc. cit.*), Vienna. Quehl, dung from Java and on deer dung, near Berlin. Thaxter (1904 *loc. cit.*), New Haven, Conn., Tabor, Iowa, Florida, Laubach, Java.

Illustrations: Berkeley, Introduction to cryptogamic botany, London, 1857, 313. Thaxter, Bot. Gaz., *17*, 1892, 389, Pl. 22 and 23, Figs. 1–11. Quehl Cent. f. Bakt., II Abt., *16*, 1906, 9, Pl. 1, Fig. 10. Jahn Kryptogamenflora der Mark Brandenburg, V, Pilze I, Lief, 2, 1911, 199, Fig. 6; Jahn, Beitrage zur botanischen Protistologie, I Die Polyangiden, Geb. Borntraeger, Liepzig, 1924, Pl. 2, Figs. 14, 15, and 16.

2. **Chondromyces aurantiacus** (Berkeley and Curtis) Thaxter. (*Stigmatella aurantiaca* Berkeley and Curtis (no description) Introduction to Cryptogamic Botany, London, 1857, 313; Berkeley (description) Notes on American fungi, Grevillea, *3*, 1874, 97; *Stilbum rhytidosporum* Berkeley and Browne 1873, 96, see Saccardo Sylloge, 1886, 571; *Polycephalum aurantiacum* Kalchbrenner and Cooke, Australian Fungi, Grevillea, *9*, 1880, 23; *Myxobotrys variabilis* Zukal, Ber. d. Bot. Ges., *14*, 1896, 340; *Chondromyces aurantiacus* Jahn, Kryptogamenflora der Mark Brandenburg, B, Pilze I, 1911. 206.)

Etymology: Latin (adj.) = orange colored.

Swarm stage (pseudoplasmodium): Flesh colored, distinctly reddish. Rods large, tapering somewhat, normally straight, rounded at either extremity, 7 to 15 by 0.6 to 1 microns, average 7 by 0.5 microns (?). Easily cultivated on nutrient agar, but on this rarely produces well formed cystophores, though cultivable on its ordinary substrate without difficulty.

Fruiting bodies: Cysts oval, elliptical or spherical, average 39 by 50 microns, at first stalked than sessile, united in small numbers at one end of cystophores, bright orange red, chestnut brown when kept moist for a considerable period or flesh colored. Cystophore colorless, often yellowish at the tip, usually simple, rarely forked, 200 to 400 microns high.

The Krzemieniewskis (Acta Soc. Bot., Potoniae, *5*, 1927, 96) have described a *Chondromyces aurantiacus* var. *frutescens* in which the fruiting body consists of a greenish, later yellowish mass of rods which develops into thick cystophore with numerous terminal cysts. The cysts are oval or spherical, sometimes with cross-striations, first orange colored, later brown, about 40 to 120 by 30 to 90 microns. The cyst rods are 2.3 to 3.4 by 0.9 to 1.0 microns.

Occurrence and habitat: Berkeley (1857 *loc. cit.*) on lichen. Berkeley and Brown (1873 *loc. cit.*) on rotten wood from Ceylon. Thaxter (1892 *loc. cit.*) in North America not uncommon on old wood and fungi. Zukal (1896

loc. cit.), Vienna. Thaxter, Bot. Gaz., *23*, 1897, 395, on antelope dung from Africa. Thaxter, Bot. Gaz., *37*, 1904, 405, Florida, Philippines. Quehl Cent. f. Bakt., II Abt., *16*, 1906, 9, dung from Java. Krzemieniewski Acta Soc. Bot. Poloniae, *4*, 1926, 1, rare in Polish soils.

Illustrations: Berkeley and Brown, (1873 *loc. cit.*) Pl. 4, Fig. 16. Kalchbrenner and Cooke (1880 *loc. cit.*). Thaxter (1892 *loc. cit.*) Pl. 23 and 24, Figs. 12–19 and 25–28. Zukal (1896 *loc. cit.*) Pl. 20. Quehl (1906 *loc. cit.*) Pl. 1, Fig. 10. Jahn Beiträge zur botanischen Protistologie, I, Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, Fig. V, p. 57, Fig. W, p. 59. Krzemieniewski (1926 *loc. cit.*) Pl. V, Figs. 57–60 (1927) var. *frutescens* Pl. VI, Figs. 27–35.

3. **Chondromyces apiculatus** Thaxter (Bot. Gaz., *23*, 1897, 405.)

Etymology: Latin (adj.) = with a small point.

Swarm stage (pseudoplasmodium): Rods 1 by 3 to 20 microns. Does not grow as well on nutrient agar as *Chondromyces crocatus* and produces cysts and cystophores rarely. Cultivated on dung. Kofler states rods are 3 to 5 microns in length.

Fruiting bodies: Cysts of variable form, cylindrical to broadly turnip-shaped, usually with basal and apical appendages, the latter longer and pointed, bright orange, 28 by 35 microns. Cysts united in a single spherical terminal head, about 200 microns in diameter. Cystophore rigid, stiff, seldom branched, to 1 mm. high, colorless, longitudinally striate. Cysts germinate at both base and apex.

Occurrence and habitat: Thaxter (1897 *loc. cit.*) on antelope dung from Africa. Thaxter (1904 *loc. cit.*) deer dung, Philippines, Florida. Baur (1906 *loc. cit.*) on rabbit dung near Berlin. Kofler (1913 *loc. cit.*) on rabbit dung near Vienna.

Illustrations: Thaxter (1897 *loc. cit.*) Pl. 30, Figs. 1 to 15. Quehl (1906 *loc. cit.*) Pl. 1, Figs. 13 to 14. Jahn (1911 *loc. cit.*) p. 199, Fig. 5.

4. **Chondromyces pediculatus** Thaxter (Bot. Gaz., *37*, 1904, 410).

Etymology: Latin (adj.) = small footed (stalked).

Swarm stage (pseudoplasmodium): Rods 0.6 to 0.7 by 2 to 4 microns.

Fruiting bodies: Cysts rounded to bell shaped, truncate at distal end, orange-yellow, when dry orange-red, 35 to 50 microns. Sessile on stalks 40 to 60 microns in length, which are arranged as an umbel on the tip of the cystophore. Cystophore 300 to 700 microns in length, solitary, simple, usually rather slender and somewhat wrinkled.

Occurrence and habitat: Thaxter (1904 *loc. cit.*), on goose dung in South Carolina.

Illustrations: Thaxter (1904 *loc. cit.*) Pl. 26, Figs. 7 to 13.

5. **Chondromyces catenalatus** Thaxter. (Bot. Gaz., *37*, 1904, 410.)

Etymology: Latin (adj.) = occurring in chains.

Swarm stage (pseudoplasmodium): Cultivated only on original substrate. Rods 1 to 1.3 by 4 to 6 microns.

Fruiting bodies: Cysts light yellow-orange, 20 to 50 by 18 microns in rosary-like chains, which may be branched once or twice, sessile on a short compact stalk, cysts separated by shriveled isthmuses. Chains to 300 microns. Cystophore simple 180 to 360 microns, cleft above, and passing over into the chains, rather broad at base and spreading somewhat on substratum. The divisions of cystophore pointed, short, slightly swollen.

Occurrence and habitat: Thaxter (1904 *loc. cit.*) on decaying poplar wood, New Hampshire.

Illustrations: Thaxter (1904 *loc. cit.*) Pl. 26, Figs. 1 to 5.

FAMILY IV. MYXOCOCCACEAE JAHN 1924.

Etymology: From generic name, *Myxococcus*.

Diagnosis: The rods become short when cysts are formed, and develop into spherical spores. Upon germination they elongate to rods, without rupturing the membrane. The type genus is *Myxococcus*.

Key to the genera of family **Myxococcaceae**

1a. Spores lie in a loose slime. Fruiting body spherical or lengthened to columnar. At the base there may be developed a kind of foot as a result of abundant slime formation.
    1. *Myxococcus*, p. 611.
2a. Spores united by a viscous slime into fruiting bodies of definite form.
    1b. Fruit body constricted or branched like coral.
        2. *Chondrococcus*, p. 614.
    2b. Spores lie in cysts of definite shape.
        3. *Angiococcus*, p. 617.

Genus 1. **Myxococcus** *Thaxter 1892.*

Etymology: Greek (noun) = slime and coccus (ball).

Diagnosis: Spherical spores in conical or spherical or occasionally ovoid upright fruiting bodies, united by a loose more or less mobile slime.

Five species, of which *Myxococcus fulvus* (Cohn *emend.* Schroeter) Jahn is the type.

Key to the species of genus **Myxococcus**.

A. Stalk lacking or indicated only by a constriction.
    a. Spore mass reddish or brownish flesh colored.
        1. *Myxococcus fulvus*.
    aa. Spore mass not as 1b.
    b. Spore mass yellowish or greenish yellow.
        2. *Myxococcus virescens*.
    bb. Spore masses light blood-red.
        3. *Myxococcus cruentus*.
B. Fruiting body with a well developed stalk, which carries the spherical spore mass above.
    a. Spores spherical.
        4. *Myxococcus stipitatus*.
    aa. Spores oval.
        5. *Myxococcus ovalisporus*.

1. **Myxococcus fulvus** (Cohn *emend.* Schroeter) Jahn. (*Micrococcus fulvus* Cohn?, Beiträge z. Biologie d. Pflanzen, *1*, Heft. 3, 1875, 181; Jahn 1924 states that the description of Cohn is too inadequate to determine whether he was dealing with a true species of the genus *Myxococcus*. Cohn described the organism from horse dung, as producing conical, rust-red droplets 1/2 mm. in diameter, the cells bound together by an intercellular slime, cells large, 1.5 microns in diameter; *Micrococcus fulvus* Schroeter, Schizomycetes, in Cohn's, Kryptogamenflora v. Schlesien *3*, 1, 1886. Observed on horse dung and rabbit dung at various localities. Jahn insists that this organism must be the same as *Myxococcus rubescens* Thaxter. *Myxococcus rubescens* Thaxter, Bot. Gaz., *17*, 1892, 403; *Myxococcus ruber* Baur, Arch. f. Protistenkunde, *5*, 1905, 95; *Myxococcus pyriformis* A. L. Smith, Jour. Bot., *39*, 1901, 71; *Myxococcus javanensis* de Kruiff, Cent. f. Bakt., II Abt., *21*, 1908, 386; *Myxococcus fulvus* Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 84.)

Etymology: Latin (adj.) = reddish yellow.

Swarm stage (pseudoplasmodium): Thaxter states that the rod masses are reddish, rods slender, irregularly curved 3 to 7 by 0.4 microns. Baur followed spore germination in hanging drop. Spores 0.8 to 1.3 microns, without structure, in five hours swollen to 1 to 1.5 microns, and no longer so refractive. The membrane is not burst, the cell becomes egg shaped, then elongate and cylindric. He regards his *Myxococcus ruber* as distinct from Thaxter's *Myxococcus rubescens* in part because of differences in spore germination. The cells become motile after doubling or trebling in length. It is a creeping motion in contact with the substrate; the cells do not "swim." Rate of motion 5 to 10 microns per minute. Rods eventually are 0.5 to 0.7 microns by 4 to 10 microns. Cell division by transverse fission. Spore formation is through shortening and rounding of the cells, the converse of germination. In hanging drop the cells tend to congregate after three days and to transform into spores. Rods sporulate in 3 to 4 hours. The rods continued to congregate, and the spore mass increases, held together by viscous matrix. Vegetative cells are light flesh color.

Gelatin is quickly liquefied, completely in 1 to 2 days, but no fruiting bodies are formed.

Kofler secured good growth on Hasting's milk agar, and determined digestion of casein.

Baur could not secure good growth on any agar medium of known composition. With peptone, sugars, etc., some growth but not normal when peptone present. He carried one strain 3½ months on peptone sugar agar. Good growth on dung agar. Addition of peptone to dung agar not significant in effect, the addition of dextrose altered the form of the fruiting bodies.

De Kruiff secured best results with a dung extract agar to which was added ammonium nitrate and potassium phosphate.

Fruiting bodies: Spherical or elongate pear shape, constricted below, often with definite slimy stalk, flesh red to brownish red, when dry rust

red to brown, about 300 microns in diameter. Spores 1 to 1.2 microns. Jahn (1924 *loc. cit.*) notes two varieties.

var. *albus*. (Latin adj. white.) Constantly white, even when transferred. Fruiting bodies somewhat smaller than the type.

var. *miniatus*. (Latin part. adj. painted with red lead or cinnabar.) Color cinnabar red, fruiting bodies somewhat larger.

The form described by de Kruiff had spores 1.6 microns in diameter.

Occurrence and habitat: Thaxter (1892 *loc. cit.*) on various decaying substances, lichens, paper, dung, etc. Smith (1901 *loc. cit.*) on rabbit dung from Wales. Baur (1904 *loc. cit.*) on cow and dog dung. de Kruiff (1908 *loc. cit.*) on stable manure in Java. Jahn (1924 *loc. cit.*) very common, on almost all specimens of dung, also on bark, decaying wood, and lichens. Krzemieniewski (1927 *loc. cit.*) very common in Polish soil. Kofler (1930 *loc. cit.*) dung of rabbit, horse, goat, mouse, roe, deer, on stem of clematis and decaying leaves and in bird nest.

Illustrations: Cohn (1875 *loc. cit.*) Pl. 6, Fig. 18. Smith (1901 *loc. cit.*) Fig. 1. Baur (1904 *loc. cit.*) Figs. 1, 2, 3, and Pl. 4, Figs. 1–13, 16. Jahn (1924 *loc. cit.*) Figs. L-M, p. 43, Figs. R, p. 47. Krzemieniewski Acta Bot. Poloniae, *4*, 1926, 1, Pl. I, Figs. 7–8. Kofler Sitzber d. Kais. Akad. Wiss. Wien. Math.-Nat. Klasse, 122 Abt., 1913, 845, Pl. 2, Figs. 10 and 12.

Cultures: Baur (1904 *loc. cit.*) states that he deposited a pure culture in the "Zentralstelle für Pilzkulturen."

2. **Myxococcus virescens** Thaxter (Bot. Gaz., *17*, 1892, 404).

Etymology: Latin (part. adj.) = becoming green.

Swarm stage (pseudoplasmodium): Rod masses greenish yellow. Rods slender, irregularly curved 3 to 7 by 0.4 microns. When cultivated in potato agar tends to lose its green color and becomes yellowish. Badian (1930) reports the presence of a dumb-bell-shaped nuclear structure which splits longitudinally in cell division, and shows autogamy preceding and a reduction division during spore formation.

Fruiting body: Spherical or conical, usually less rounded than other species of the genus, yellowish, occasionally greenish, in culture on artificial media, easily becoming white, 150 to 500 microns. The slime deliquescing in continued moisture. Spores large, about 2 microns.

Occurrence and habitat: Thaxter (1892 *loc. cit.*), on hen's and dog's dung, New England. Jahn (1924 *loc. cit.*) not very abundant on dung of rabbit, horse, stag and black cock. Krzemieniewski (1927 *loc. cit.*) common in soil in Poland. Badian (1930 *loc. cit.*) Poland.

Illustrations: Krzemieniewski Acta Bot. Poloniae, *4*, 1926, 1, Pl. I, Fig. 9. Badian Acta Soc. Bot. Poloniae, *7*, 1930, 55, Pl. 1, 8 figures.

3. **Myxococcus cruentus** Thaxter (Bot. Gaz., *23*, 1897, 395; *Chondrococcus cruentus* Krzemieniewski, Acta Soc. Bot., Poloniae, *5*, 1927, 79.)

Etymology: Latin (adj.) = blood-red.

Swarm stage (pseudoplasmodium): Rods 0.8 by 3 to 8 microns. Was not cultivated.

Fruiting body: Cysts regularly spherical, 90 to 125 microns, blood-red. Slime forms on the surface a more or less definite membrane, in which the spores lie. Spores oval or irregularly oblong about 0.9 to 1 by 1.2 to 1.4 microns. Cysts are densely aggregated.

Occurrence and habitat: Thaxter (1897 *loc. cit.*) on cow dung. Tennessee.

Krzemieniewski (1927 *loc. cit.*) rare in Polish soils.

Illustrations: Thaxter (1897 *loc. cit.*) Pl. 31, Figs. 28–29.

4. **Myxococcus stipitatus** Thaxter (Bot. Gaz., *23*, 1897, 395.)

Etymology. Latin (adj.) = stalked.

Swarm stage (pseudoplasmodium): Rods 0.5 to 0.7 by 2 to 7 microns or longer. Grows well on nutrient agar, but does not fruit readily.

Fruiting body: Spore mass nearly spherical, 175 microns in diameter, delinquescent, sessile on a well developed compact stalk, white to yellowish and flesh color. Spores 0.8 to 1.2 by 1.0 to 1.15 microns. Stalk 100 to 200 microns long, 30 to 50 microns wide.

Occurrence and habitat: Thaxter (1897 *loc. cit.*) repeatedly on dung in laboratory cultures at Cambridge, Mass., Maine, Tennessee. Krzemieniewski (1927 *loc. cit.*) common in Polish soils.

Illustrations: Thaxter (1897 *loc. cit.*) Pl. 31, Figs. 30 to 33. Krzemieniewski Acta Bot. Poloniae, *4*, 1926, 1, Pl. II, Figs. 13–14.

5. **Myxococcus ovalisporus** Krzemieniewski. (Acta Soc. Bot., *4*, 1926, 15.)

Etymology: Latin (adj.) = oval spored.

Swarm stage (pseudoplasmodium). Not described.

Fruiting bodies: Produces almost spherical, characteristically shortened, ovoid spore masses of light milky yellow color. These are often raised on a poorly developed stalk. This stalk always shows some bacterial cells remaining, and in this and color is differentiated from *M. stipitatus*. From the base of the stalk or directly from the substrate one or more small fruiting bodies develop. Spores are oval, sometimes irregularly spherical 1.3 to 1.9 by 1.0 to 1.4 microns. In culture retains its differences from *M. stipitatus*. The latter sporulates best at room temperature, but *M. ovalisporus* in the thermostat.

Occurrence and habitat: Develops on rabbit dung (sterilized) on soil in Poland (Krzemieniewski).

Genus II. Chondrococcus *Jahn 1924.*

Synonymy: A segregate from *Myxococcus* Thaxter.

Etymology: Greek (noun) grain and ball (coccus).

Diagnosis: Spores embedded in a viscous slime which hardens. Fruiting bodies divided by joints or constrictions, often branched, usually relatively small.

Five species are included, of which the first described by Thaxter and best described, *Chondrococcus coralloides* (Thaxter) Jahn may be designated

as the type. The first species listed by Jahn is regarded as doubtful and should not be regarded as the type for there is no evidence that Jahn ever saw the species.

Key to the species of genus **Chondrococcus.**

1. Erect, simple or somewhat branched fruiting bodies.
   a. Fruiting body constricted or jointed.
      1. *Chondrococcus coralloides.*
   aa. Fruiting body simple, columnar, club or cushion shaped.
   b. Fruiting body thick below, lesser above.
      2. *Chondrococcus cirrhosus.*
   bb. Not as in b.
   c. Spores 1.6 to 2 microns in diameter.
   d. Fruiting body cushion shaped.
      3. *Chondrococcus megalosporus.*
   dd. Fruiting body branched.
      4. *Chondrococcus macrosporus.*
   cc. Fruiting body smaller below, upward club shaped. Spores 1 to 1.2 microns in diameter.
      1A *Chondrococcus coralloides* var. *clavatus.*
2. Recumbent, simple swelling or "cyst heap" constituting the fruiting bodies.
   a. Cysts 70 to 170 microns, without definite envelope, in swollen brain-like arrangement.
      5. *Chondrococcus cerebriformis.*
   aa. Cysts 30 to 35 microns, numerous and embedded in a thick slime envelope.
      1B *Chondrococcus coralloides* var. *polycystus.*

1. **Chondrococcus coralloides** (Thaxter) Jahn. (*Myxococcus coralloides* Thaxter, Bot. Gaz., *17*, 1892, 404; *Myxococcus digitatus* Quehl, Cent. f. Bakt., II Abt., *16*, 1906, 18 (*pro parte*); *Myxococcus clavatus* Quehl, *ibid.*; *Myxococcus polycystus* Kofler, Sitzber d. Kais, Akad. Wiss., Wien. Math.-Nat. Klasse., 122 Abt., 1913, 865 (*pro parte*); *Myxococcus exiguus* Kofler *ibid.*, p. 867 (*pro parte*); *Chondrococcus polycystus* Krzemieniewski, Act. Soc. Bot. Poloniae, *4*, 1926, 46.)

Etymology: Latin (adj.) = coral-like.

Swarm stage (pseudoplasmodium): Rod masses pale pinkish, thin, rods slender, curved 4 to 7 by 0.4 microns. Readily cultivated on lichens and on potato agar.

Fruiting bodies: Very variable in shape, usually with rounded coral-like processes, recumbent or upright, sometimes with finger-like outgrowths or rounded constrictions, usually small, about 50 microns in diameter, protuberances 20 to 30 microns wide, light rose to flesh color. Spores 1 to 1.2

microns. Jahn concludes that the species segregated by Quehl and by Kofler are of varietal rank only. Krzemieniewski (1926) regards *Chondrococcus polycystus* (Kofler) Krzemieniewski as a distinct species.

Occurrence and habitat. Thaxter (1892) uncommon in America, on lichens. Very common in Europe. Jahn (1924) relatively common. On dung of rabbit, hare, horses, deer, old bark and old lichens. Goat dung from Lapland and Italy. Kofler (1913) dung of field mice, horses, hares, goats, roe and deer. Krzemieniewski (1927) common in Polish soil.

Illustrations: Thaxter (1892 *loc. cit.*) Pl. 24, Figs. 29–33. Quehl (1906 *loc. cit.*) Pl. 1, Figs. 1 and 9. Kofler (1913 *loc. cit.*) Pl. 1, Fig. 4, Pl. 2, Fig. 9. Krzemieniewski (1926 *loc. cit.*) Pl. II, Figs. 15–18. Jahn (1924 *loc. cit.*) Fig. Y., p. 87.

1A. **Chondrococcus coralloides** var. **clavatus**, varies from *Chondrococcus coralloides* in having fruiting bodies simple or branched rather than constricted or jointed.

1B. **Chondrococcus coralloides** var. **polycystus**, varies from *Chondrococcus coralloides*, in its fruiting bodies being simple swellings or "cyst heaps" rather than branched, and in being recumbent rather than erect.

2. **Chondrococcus cirrhosus** (Thaxter) Jahn. (*Myxococcus cirrhosus* Thaxter, Bot. Gaz., *23*, 1897, 409; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1911, 200.)

Etymology: Greek (adj.) = tawny.

Swarm stage (pseudoplasmodium): Rods 0.8 by 2 to 5 microns.

Fruiting bodies: Elongate, upright, thickened below, slender above, extended to a rounded point, 50 to 100 microns long, 20 microns in diameter at base, light red to flesh colored. Spores about 1 micron.

Occurrence and habitat: Thaxter (1897 *loc. cit.*) once only on grouse dung, Mass.

Illustrations: Thaxter (1897 *loc. cit.*) Pl. 31, Figs. 25–27.

3. **Chondrococcus megalosporus** Jahn. (Beiträge zur botanischen Protistologie. I. Die Polyangiden. Geb. Borntraeger, Leipzig, 1924, 86.)

Etymology: Greek (adj.) = large spored.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: About 80 to 160 microns wide, rounded, cushion shaped, dark flesh color. Spores 2 microns.

Occurrence and habitat: Jahn (1924 *loc. cit.*) on stag dung near Berlin.

Illustrations: Jahn (1924 *loc. cit.*) Fig. Y, i to k, p. 87.

4. **Chondrococcus macrosporus** Krzemieniewski. (Acta Soc. Bot.. Poloniae, *4*, 1926). According to Krzemieniewski, not to be confused with Zukal's species, *Myxococcus macrosporus* (Ber. d. deutsch. Bot. Gesellsch.. *15*, 1897, 542.)

Etymology: Latin (adj.) = large-spored.

Swarm stage (pseudoplasmodium): Not described.

Fruiting bodies: Much like *C. coralloides*, differing in color and in size

of spores. Spores 1.6 to 2.0 microns. Fruiting body yellow or light brown color, with long branches.

Occurrence and habitat: Krzemieniewski (1926 *loc. cit.*) found it first on leaves, later isolated from soil on rabbit dung.

Illustrations: Krzemieniewski (1926 *loc. cit.*) Pl. II, Fig. 19.

5. **Chondrococcus cerebriformis** (Kofler) Jahn. (*Myxococcus cerebriformis* Kofler. Sitzber d. Kais. Akad. Wiss., Wien. Math.-Nat. Klasse, 122 Abt., 1913, 866; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 86.)

Etymology: Latin (adj.) = brain shaped.

Swarm stage (pseudoplasmodium): Rods 4 to 12 microns.

Fruiting bodies: About 1 mm. long, clumped masses with swollen upper surface, brain like, violet rose, "often lead gray." Cysts 100 to 170 microns, without slime envelope. Spores 1.1 to 1.6 microns. Jahn (1924 *loc. cit.*) suggests that this may be *Archangium gephyra*.

Occurrence and habitat: Kofler (1913 *loc. cit.*) on hare dung in the vicinity of Vienna.

Illustrations: Kofler (1913 *loc. cit.*) Pl. 2, Figs. 7 and 8.

Genus III. Angiococcus *Jahn 1924.*

A segregate from *Myxococcus* Thaxter.

Etymology: Greek (noun) vessel and coccus (ball).

Diagnosis: Fruiting body consisting of numerous round (disk-shaped) cysts, cyst wall thin, spores within.

One species only, hence the type by monotypy, *Angiococcus disciformis* (Thaxter) Jahn.

1. **Angiococcus disciformis** (Thaxter) Jahn. (*Myxococcus disciformis* Thaxter, Bot. Gaz., *37*, 1904, 412; Jahn, Beiträge zur botanischen Protistologie. I. Die Polyangiden, Geb. Borntraeger, Leipzig, 1924, 89.)

Etymology: Latin (adj.) = disk-shaped.

Swarm stage (pseudoplasmodium): Rods 0.5 to 0.6 by 2 to 3 microns.

Fruiting bodies: Cysts disk-shaped, crowded, sessile, attached by a more or less ragged scar-like insertion, or in masses. Cysts yellowish when young, when old dark orange-yellow, about 35 by 10 microns. Cyst wall distinct, thin, becoming very slightly wrinkled. Spores irregularly spherical, embedded in viscous slime, difficult to see in the ripe cyst.

Occurrence and habitat: Thaxter (1904 *loc. cit.*) Dung of muskrat and deer. Massachusetts and New Hampshire. Krzemieniewski (1927 *loc. cit.*) rare in Polish soils.

Illustrations: Thaxter (1904 *loc. cit.*) Pl. 27, Figs. 19–21. Krzemieniewski Acta Soc. Bot., Poloniae, *4*, 1926, 1, Pl. II, Figs. 21–22

ORDER VI. SPIROCHAETALES BUCHANAN, 1918.

Protozoon-like in many characters. Cells usually relatively slender, flexous spirals; multiplication of cells apparently by longitudinal division in some types, by transverse division in others, or both.

One family is recognized, namely, *Spirochaetaceae*.

FAMILY I. SPIROCHAETACEAE SWELLENGREBEL, 1907.

Characters those of the Order.

Key to the genera of family **Spirochaetaceae.**

A. Usually saprophitic, free-living in water.
  1. Protoplasm spirally wound around an elastic axis filament.
    Genus I. *Spirochaeta*, p. 618.
  2. Cross section circular.
    Genus II. *Saprospira*, p. 621.

B. Usually parasitic.
  1. Possessing a "crest" or ridge. Parasitic in mussels.
    Genus III. *Cristispira*, p. 622.
  2. Without crest. Parasitic in warm blooded animals and in man.
    Genus IV. *Borrelia*, p. 624.
    Genus V. *Treponema*, p. 627.
  3. Short, sharply twisted spirals. Parasitic in rodents and in man.
    Genus VI. *Leptospira*, p. 629.

Genus I. Spirochaeta *Ehrenberg, 1833.*

Non-parasitic, with flexible, undulating body and with or without flagelliform tapering ends. Common in sewage and foul waters.

The type species is *Spirochaeta plicatilis* Ehrenberg.

Key to the species of genus **Spirochaeta.**

1. Large spirals with rounded ends.
    1. *Spirochaeta plicatilis.*
    2. *Spirochaeta marina.*
    3. *Spirochaeta eurystrepta.*
2. Smaller spirals with pointed ends.
    4. *Spirochaeta stenostrepta.*
    5. *Spirochaeta daxensis.*

1. **Spirochaeta plicatilis** Ehrenberg. (Die Infusionstierchen, 1838, 83.)

Cylindrical: 0.5 to 0.75 by 100 to 500 microns, with blunt ends.

Spiral amplitude: 2.0 microns, regular.

Spiral depth: 1.5 microns, regular.

Waves, several, large, inconstant, irregular.

Axial filament distinct in stained specimens, consisting of chitin or cutin-like substance.

Flexible, elastic.

Chambered structure absent.

Membrane absent.

Crista absent.

Terminal finely spiral filament absent.
Flagella absent.
Highly motile end portion absent.
Division, transverse.
Stains violet by Giemsa's stain and gray by iron-hemotoxylin.
Plasma spirals stain with eosin, rubin, etc. Contain volutin granules.
Trypsin digestion: Axial filament resistant.
Bile salts (10 per cent): Becomes shadowy, pale, but is not digested.
Saponin (10 per cent): Lives 30 minutes. Later becomes shadowy, but is not dissolved.
Grows best under low oxygen tension.
Optimum temperature 20° to 25°C.
Habitat: Free-living in fresh or salt water.

2. **Spirochaeta marina** Zuelzer. (Arch. f. Protistenkunde, *24*, 1912, 1.)
Cylindrical, 0.5 by 100 to 200 microns.
Spiral amplitude.
Spiral depth.
Waves.
Axial filament present.
Flexible, elastic.
Chambered structure absent.
Membrane absent.
Crista absent.
Terminal finely spiral filament absent.
Flagella absent.
Highly motile end portion absent.
Division transverse.
Contains smaller and more irregularly distributed volutin granules than *Spirochaeta plicatilis*.
Plasma spirals stain?
Trypsin digestion.
Bile salts (10 per cent).
Saponin (10 per cent).
Grows best at low oxygen tension.
Optimum temperature 20°C.
Habitat: Sea water.

3. **Spirochaeta eurystrepta** Zuelzer. (Arch. f. Protistenkunde, *24*, 1912, 1.)
Cylindrical: 0.5 micron in thickness and up to 300 microns in length
Spiral amplitude. More shallow than spirals of *Spirochaeta plicatilis*.
Spiral depth.
Waves.
Axial filament present.
Flexible, elastic.
Chambered structure absent.

Membrane absent.
Crista absent.
Terminal finely spiral filament absent.
Flagella absent.
Highly motile end portion absent.
Division, transverse.
Fewer volutin granules than in *Spirochaeta plicatilis*.
Plasma spirals stain.
Trypsin digestion.
Bile salts (10 per cent).
Saponin (10 per cent).
Optimum temperature 20°C.
Habitat: Swamp water and in grossly polluted water containing H_2S.

4. **Spirochaeta stenostrepta** Zuelzer. (Arch. f. Protistenkunde, *24*, 1912, 1.)

Cylindrical: 0.25 micron in thickness and 20 to 60, and occasionally up to 200 microns in length, with pointed ends.

Spiral amplitude very narrow with steep windings.
Spiral depth.
Waves.
Axial filament present.
Flexible, elastic.
Chambered structure absent.
Membrane absent.
Crista absent.
Terminal finely spiral filament absent.
Flagella absent.
Highly motile end portion absent.
Division, transverse.
Fewer volutin granules than in *Spirochaeta plicatilis*.
Plasma spirals stain.
Trypsin digestion.
Bile salts (10 per cent).
Saporin (10 per cent).
Optimum temperature 20°C.
Habitat: Water containing H_2S.

5. **Spirochaeta daxensis** Cantacuzene. (Compt. rend. Soc. d. Biol., *68*, 1910, 75.)

Large spirals: 0.5 to 2.5 by 30 to 100 microns, possessing a longitudinal chromatin filament, and tapering at the ends.

They are flattened and exhibit a double series of curls, smaller waves being superimposed on larger undulations.

Optimum temperature 44° to 52°C.
Habitat: Found in water of hot spring of Dax (52° to 56°C.).

Genus II. Saprospira *Gross, 1911.*

Non-parasitic forms similar to *Cristispira* but without the flattened ridge or "crista" which is, if present, here replaced by a straight columella or thickening of the periplast.

The type species is *Saprospira grandis* Gross.

1. **Saprospira grandis** Gross. (Mitteil. a. d. Zool. Station zu Naepel, *20*, 1910, 41.)

Cylindrical, 1.2 by 80 microns in length, with obtuse ends.
Spiral amplitude is 24 microns.
Spiral depth.
Waves large, inconstant, shallow, irregular, 3 to 5 in number, sometimes almost straight.
Axial filament absent.
Chambered structure present.
Membrane distinct.
Division, transverse.
Flexible, elastic.
Crista absent.
Terminal finely spiral filament absent.
Flagella absent.
Highly motile end portion absent.
Plasmic spirals.
Trypsin digestion.
Bile salts (10 per cent).
Saponin (10 per cent).
Habitat: Free-living in foraminiferous sand. Found in intestinal tract of the oyster.

2. **Saprospira puncta** Dimitroff. (Jour. of Bact., *12*, 1926, 146.)

Large spirals: 1.0 by 86 microns with pointed ends.
The spiral amplitude is 4 to 8 microns.
The average number of turns is 3.
Axial filament absent.
Chambered structure present.
Membrane.
Division probably transverse.
Habitat: Found in oysters.

3. **Saprospira lepta** Dimitroff. (Jour. of Bact., *12*, 1926, 144.)

Large spirals: 0.5 by 7.0 microns, with pointed ends.
The spiral amplitude ranges from 5 to 13 microns.
The spiral width varies from 1.6 to 4.8 microns.
The average number of turns is 6.
Axial filament absent.

Chambered structure present.
Membrane.
Division probably transverse.
Habitat: Found in oysters in Baltimore, Md.

Genus III. Cristispira *Gross, 1910.*

Giant forms with undulating body and peculiar flattened ridge erroneously called an "undulating membrane" which runs the length of the body. Parasitic in molluscs.

The type species is *Cristispira balbianii* Certes.

1. **Cristispira balbianii** Certes. (Bull. Soc. Zool. de France, 7, 1882, 347.)

Cylindrical: 1.0 to 3.0 by 40 to 120 microns, with obtuse ends.
Spiral amplitude is 8 microns.
Spiral depth is 1.6 microns.
Waves 2 to 5, sometimes more, large irregular, shallow.
Axial filament absent.
Chambered structures present.
Membrane distinct.
Flexible, elastic.
Crista present, a ridge-like membrane making one to two complete turns.
Terminal finely spiral filament absent.
Flagella absent.
Highly motile end portion absent.
Division, transverse.
Stains: Cell membrane behaves like chitin or cutin substance. Stains violet by Giemsa's solution, and light gray by iron-hemotoxylin.
Trypsin digestion: Membrane resistant, crista and chambers disappear.
Bile salt (10 per cent): Crista quickly dissolves.
Saponin (10 per cent): Crista becomes fibrillar, then indistinct.
Habitat: Parasitic in alimentary tract of shell-fish.

2. **Cristispira anodontae** Keysselitz. (Arb. a. d. Kaiserl. Gesundheitsamte, *23*, 1906, 566.)

Large spirals: 0.8 to 1.2 by 44 to 88 microns with sharply pointed ends; flattened and possessing an undulating membrane. The periplast is fibrillar in appearance and there is a dark granule at each end of the undulating membrane. The chromatin material is distributed in the form of globules or elongated bands.

The average width of the spiral is 2 microns.
The average wave length is 8 microns.
The number of complete turns ranges from 5 to 11.
Habitat: Found in the crystalline style of fresh water mussels, *Anodonta cygnea* and *A. mutabilis*, also in intestinal tract of oysters.

3. **Cristispira interrogationis** Gross. (Mitteil. a. d. Zool. Station zu Naepel, *20*, 1910, 41.)

Spirals: 0.5 by 25 microns, with pointed ends.

Habitat: Found in the intestinal canal of the mollusc *Pecten jacobaeus.*

4. **Cristispira pinnae** Gonder. (Cent. f. Bakt., *47*, 1908, 491.)

Spirals: 0.5 to 3.0 by 10 to 60 microns, round in section with blunt ends, the one being slightly more pointed than the other.

They have a ridge or comb running along one side but no terminal filaments.

Chambered structure distinct.

The chromatin granules are grouped in fours.

An undulating membrane can be demonstrated.

Division appears to occur rapidly by longitudinal division.

Habitat: Found in the intestinal canal of the mollusc *Pecten jacobaeus.*

5. **Cristispira mina** Dimitroff. (Jour. of Bact., *12*, 1926, 159.)

Spirals: 0.6 to 0.8 by 38 to 76 microns, with bluntly pointed ends.

The spiral amplitude is 12 microns.

The width of the spirals is 3.2 to 5.6 microns.

The average number of turns is 4.

Multiplication by transverse division.

Crista present.

Habitat: Found in oysters.

6. **Cristispira tenuis** Dimitroff. (Jour. of Bact., *12*, 1926, 160.)

Spirals: 0.7 by 54 microns.

The spiral amplitude is 8 microns.

The width of spirals is 2.4 microns.

Habitat: Found in oysters.

7. **Cristispira modiolae** Schellack. (Arb. a. d. Kais. Gesundheitsamte, *30*, 1909, 379; Dimitroff, Jour. of Bact., *12*, 1926, 157.)

Long spirals, 0.8 by 36 to 78 microns, with blunt ends.

The spiral amplitude is 20 microns.

The width of the spirals is 4 to 6.8 microns.

The average number of turns is 3.

The chromatin material shows long darkly stained blocks.

The crista is narrow, showing no fibrillar structure.

Habitat: Found in mussels and oysters.

8. **Cristispira spiculifera** Schellack. (Arb. a. d. Kais. Gesundheitsamte, *30*, 1909, 379; Dimitroff, Jour. of Bact., *12*, 1926, 157.)

Spirals: 0.7 by 28 to 35 microns with tapering filament on each end.

Spiral amplitude is 6.4 microns.

The width of the spirals is 2 microns.

No crista could be demonstrated, probably because of failure to stain pH.

The chromatin material is distributed in wide bands.

Habitat: Found in mussels.

Genus IV. **Borrelia** *Swellengrebel, 1907.*

Small, parasitic, spiral forms; flexible, with terminal filaments. The spirals are large, wavy, three to five in number.

The type species is *Borellia gallinarum* Swellengrebel.

Note: The generic name *Spironema* Vuillemin used in the first edition of the Manual is invalid because of prior use for other organisms.

1. **Borrelia gallinarum** Swellengrebel. (Spirille de la poule, Marchoux and Salimbein, Ann. de l'Inst. Pasteur, *17*, 1903, 569; Swellengrebel, Ann. de l'Inst. Pasteur, *21*, 1907, 582; *Spironema gallinarum* Bergey et al., Manual, 1923, 425.)

Spirals: 0.25 to 0.3 by 8 to 16 microns, with two or more turns, the distance between the curves being 1.8 microns. Terminal granules are often seen. The organism possesses a delicate, finely curved projection at the extremities.

Can be cultivated under anaerobic conditions. Cultures are without perceptible odor.

Habitat: Cause of septicaemia in chickens. Transmitted by bites of ticks—*Argas percicus, A. miniatus, A. reflexus* and *Ornithodorus moubata.* Can be transmitted to rabbits.

2. **Borrelia recurrentis** (Obermeier) Bergey et al. (Obermeier, Berlin. Klin. Wochenschr., 1873, 152; Lebert, Ziemssen's Handbuch, *2*, 1874, 267; *Spironema recurrentis* Bergey et al., Manual, 1st ed., 1923, 424; Bergey et al., Manual, 2nd ed., 1925, 433.)

Cylindrical or slightly flattened, 0.35 to 0.5 by 8 to 16 microns, with pointed ends.

Spiral amplitude 1.5 microns.

Spiral depth.

Spirals large, wavy, inconstant, about five in number.

Axial filament probably present.

Membrane delicate, flexible, double contoured.

Chambered structure absent.

Crista absent.

Terminal finely spiral filament present.

Flagella absent.

Highly motile end portion absent.

Division transverse, possibly also longitudinal.

Stains: Membrane difficult to differentiate. Stains uniformly with Romanowsky stain.

Body stains violet with Giemsa's solution.

Bile salts (10 per cent): Disintegration complete.

Saponin (10 per cent): Immobilized in 30 minutes, then broken up in a few hours. In some the axial filament is laid bare.

Habitat: The cause of European relapsing fever. Transmissible to man, monkeys, mice and rats. Found in the common bed bug—*Cimex lectularius.*

3. **Borrelia duttonii** (Dutton and Todd) Bergey et al. (British Med. Jour., 1905, *2*, 1259; *Spironema duttoni* Bergey et al., Manual, 1st ed., 1923, 424; Bergey et al., Manual, 2nd ed., 1925, 434.)

Spiral forms: 0.2 to 0.5 by 14 to 16 microns, showing a long regularly curved, delicate projection at each extremity.

Growth occurs under anaerobic conditions in serum-water medium containing fresh tissue.

Habitat: The cause of African relapsing fever. Transmitted to man through the bite of the tick—*Ornithodorus moubata*. Pathogenic for mice and rats.

4. **Borrelia kochii** (Novy) Bergey et al. (Jour. of Infect. Dis., *3*, 1906, 291; *Spironema kochii* Bergey et al., Manual, 1st ed., 1923, 425; Bergey et al., Manual, 2nd ed., 1925, 434.)

Morphologically similar to *Borrelia duttonii* but serologic differences have been demonstrated.

Both transverse and longitudinal division has been seen.

Can be cultivated.

Habitat: The cause of African relapsing fever. Pathogenic for mice and rats.

5. **Borrelia novyi** (Shellack) Bergey et al. (Spirochaete from relapsing fever, Norris, Jour. of Infect. Dis., *3*, 1906, 266; Shellack, Arbeit. a. d. Kaiserl. Gesundheitsamte, *28*, 1908, 354; *Spironema novyi* Bergey et al., Manual, 1st ed., 1923, 425; Bergey et al., Manual, 2nd ed., 1925, 434.)

Spirals: 0.3 by 17 to 20 microns. Resembles *Borrelia recurrentis* in morphology but differs in serologic reactions.

Can be cultivated.

Habitat: The cause of American relapsing fever.

6. **Borrelia berbera** (Sergent and Foley) Bergey et al. (Bull. Soc. Path. Exotique, *1*, 1908, 174; *Spironema berbera* Be gey et al., Manual, 1st ed., 1923, 425; Bergey et al., Manual, 2nd ed., 1925, 435.)

Spirals: 0.2 to 0.3 by 12 to 18 microns, with 4 to 8 turns.

Habitat: The cause of relapsing fever in Algiers, Tunis and Tripoli.

7. **Borrelia carteri** (Mackie) Bergey et al. (Ann. of Trop. Med. and Parasitology, *1*, 1907, 157; Indian Med. Gazette, *44*, 1908, 370; *Spironema carteri* Bergey et al., Manual, 1st ed., 1923, 425.)

Spirals: 0.2 to 0.5 by 10 to 30 microns.

Habitat: The cause of relapsing fever in India. Transmitted by the Indian bed bug—*Cimex rotundatus*. Transmissible to monkeys, rabbits, guinea pigs, rats and mice.

8. **Borrelia theileri** (Laveran) Bergey et al. (Compt. rend. Acad. Sci., Paris, *136*, 1903, 939; *Spironema theileri* Bergey et al., Manual, 1st ed., 1923, 425; Bergey et al., Manual, 2nd ed., 1925, 435.)

Spirals: 0.25 to 0.3 by 20 to 30 microns, with pointed ends.

Habitat: Found in cattle suffering from a relapsing, febrile disease. Transmitted by the tick—*Rhipicephalus decoloratus*.

9. **Borrelia glossinae** (Novy) Bergey et al. (*Spirillum glossinae* Novy, Jour. of Infect. Dis., *3*, 1906, 385; *Spironema glossinae* Bergey et al., Manual, 1st ed., 1923, 425; Bergey et al., 1925, 435.)

Spiral forms: 0.2 by 8 microns, with four turns.

Spiral amplitude: 1.3 microns.

Habitat: Found in the stomach contents of the tse-tse fly—*Glossina palpalis*.

10. **Borrelia muris** (Wenyon) Bergey et al. (Jour. of Hyg., *6*, 1906, 580; *Spironema muris* Bergey et al., Manual, 1st ed., 1923, 425; Bergey et al., Manual, 2nd ed., 1925, 435.)

Spirals: 0.2 by 3 to 7 microns. Multiply by transverse division.

Habitat: Found in the blood of house mice.

11. **Borrelia anserina** (Sakharoff) Bergey et al. (*Spirochaeta anserina* Sakharoff, Ann. de l'Inst. Pasteur, *5*, 1891, 564; *Spironema anserina* Bergey et al., Manual, 1st ed., 1923, 426; Bergey et al., Manual, 2nd ed., 1925, 435.)

Spirals: 0.3 by 10 to 20 microns. Multiplies by transverse division.

Habitat: Found in geese suffering from a febrile disease.

12. **Borrelia vincentii** (Blanchard) Bergey et al. (Arch. f. Parasitenkunde, *10*, 129; *Spironema vincenti* Bergey et al., Manual, 1st ed., 1923, 426; Bergey et al., Manual, 2nd ed., 1925, 435.)

Spirals: 0.3 by 12 to 25 microns.

Habitat: The oral cavity. Occurs in association with the so-called "fusiform" bacillus in Vincent's angina and allied infections.

13. **Borrelia phagedenis** (Noguchi) Bergey et al. (*Spirochaeta phagedenis*, Jour. Expr. Med., *16*, 1913, 261; *Spironema phagedenis* Bergey et al., Manual, 1st ed., 1923, 426; Bergey et al., Manual, 2nd ed., 1925, 267.)

Spirals: 0.7 to 0.8 by 10 to 15 microns, showing one or two curves, with fairly pointed extremities. Long forms show a nodular swelling in the middle. There is no flagellum, terminal projection, or undulating membrane.

Stains red with Giemsa's stain.

Can be cultivated under strict anaerobic conditions.

Habitat: Isolated from phagedenous ulcer. Causes acute inflammation in rabbits and *Macaccus rhesus* monkey.

14. **Borrelia refringens** (Schaudinn) Bergey et al. (Arb. a. d. Kaiserl. Gesundheitsamte, *22*, 1905, 527; *Spironema refringens* Bergey et al., Manual, 1st ed., 1923, 426, Bergey et al., Manual, 2nd ed., 1925, 436.)

Spirals: 0.5 to 0.75 by 20 to 35 microns. The number of curves differs. The spiral amplitude is 3 microns. The ends are pointed with curved, flagella-like projections. The body of the organism is cylindrical.

Growth occurs under anaerobic conditions in serum water medium containing fresh tissue.

Habitat: Found around the genitalia of man.

15. **Borrelia hyos** Bergey et al. (Hog cholera virus, King and Baeslach, Jour. Infect. Dis., *12*, 1912, 39; *Spironema hyos* Bergey et al., Manual, 1st ed., 1923, 426; Bergey et al., Manual, 2nd ed., 1925, 436.)

Short, thick spiral.

Cultivable in blood and in ascitic broth medium.

Strict anaerobe.

Habitat: Occurs in the blood, intestinal ulcers and other lesions of hogs suffering from "hog cholera."

Genus V. Treponema *Schaudinn, 1905.*

Parasitic and frequently pathogenic forms with undulating or rigid spirilliform body. Without crista or columella. With or without flagelliform tapering ends.

The type species is *Treponema pallidum* (Schaudinn and Hoffman) Schaudinn.

1. **Treponema pallidum** (Schaudinn and Hoffman) Schaudinn. (*Spirochaete pallidum* Schaudinn and Hoffman, Arb. a. d. Kaiserl. Gesundheitsamte, *22*, 1905, 527; Schaudinn, Deutsche med. Wochenschr., *31*, 1905, 1728.)

Cylindrical: 0.25 to 0.3 by 6 to 14 microns, with pointed ends.

Spiral amplitude: 1.0 micron, regular.

Spiral depth: 0.5 to 1.0 micron, very constant.

Waves, one or more slight, undulating curves may be present.

Axial filament doubtful. The whole seems to consist of a spirally wound axial filament.

Chambered structure absent.

Membrane doubtful, if there is one present it must be flexible.

Crista absent.

Terminal finely spiral filament present, and easily seen in cultures.

Flagella absent.

Highly motile end portion absent.

Division, transverse or possibly also longitudinal.

Staining properties. Membrane not recognizable. Body stains pink with Giemsa's solution.

Trypsin digestion: Resists digestion for many days.

Bile salts (10 per cent): Disintegration complete.

Saponin (10 per cent): Broken up in time.

Cultivable under anaerobic conditions in serum-water containing fresh tissue.

Habitat: The cause of syphilis.

2. **Treponema pertenue** Castellani. (Jour. of Trop. Med., *8*, 1905, 253.)

Spirals: 0.25 to 0.3 by 18 to 20 microns.

Cultivable under anaerobic conditions.

Habitat: The cause of yaws—*Frambesia tropica.*

3. **Treponema microdentium** Noguchi. (Jour. of Exp. Med., *15*, 1912, 81.)

The organism is less than 0.25 micron in thickness in the middle and tapers toward each extremity, which is pointed. The length varies with age but may reach 8 microns and show an average of 14 curves. Sometimes a long, thin flagella-like projection is observed at each extremity.

Growth occurs under anaerobic conditions in serum water medium containing fresh tissue. The serum is slightly coagulated and gives off a strong, fetid odor.

Habitat: Normal oral cavity.

4. **Treponema macrodentium** Noguchi. (Jour. of Exp. Med., *15*, 1912, 81.)

Spirals with abruptly tapering extremities. They are 0.7 to 1.0 by 3 to 8 microns, with 2 to 8 curves.

Growth occurs under anaerobic conditions. The cultures do not give off a putrid odor.

Habitat: Normal oral cavity.

5. **Treponema mucosum** Noguchi. (Jour. of Exp. Med., *16*, 1913, 194.)

Spirals: 0.25 to 0.3 by 8 to 12 microns. The number of curves varies from 6 to 8. Both extremities are sharply pointed and often possess a minute curved projection, 8 to 10 microns long.

Cultivable under anaerobic conditions, forming mucin.

The cultures give off a strong, putrid odor.

Takes the red in Giemsa's stain.

Habitat: Found in pyorrhea alveolaris. It possesses pyogenic properties.

6. **Treponema calligyrum** Noguchi. (Jour. of Exp. Med., *17*, 1913, 96.)

Spirals: 0.35 to 0.4 by 6 to 14 microns, average from 9 to 12 microns.

Curves are regular and deep, the distance between the curves is about 1.6 microns and the depth of the curves is about 1.0 to 1.5 microns.

The organism is of uniform width until near the extremities which end in sharp points with delicate projections.

Waves, 5 to 8, according to spiral amplitude.

Cultivable under anaerobic conditions.

Stains reddish-violet with Giemsa's stain.

Habitat: Isolated from smegma. Non-pathogenic.

7. **Treponema minutum** Noguchi. (Jour. of Exp. Med., *27*, 1918, 671.)

Spirals: 0.25 to 0.3 by 3 to 14 microns, the average length being 7 to 10 microns.

Spiral amplitude: 0.9 to 1.0 micron.

Spiral depth: 0.2 to 0.5 micron.

Waves from 7 to 10, according to length.

Cultivable under anaerobic conditions.

Cultures do not exhibit a putrid odor.

Habitat: Found around the genitalia of man.

8. **Treponema elusum** (Wolbach and Binger) Bergey et al. (*Spirochaeta elusa* Wolbach and Binger, Jour. of Med. Research, *30*, 1914, 9; Bergey et al., Manual, 1st ed., 1923, 428.)

Cylindrical, variable in size from exceedingly motile forms 4 to 8 microns in length to long, motionless forms. Thickness varies with the medium.

Spiral amplitude: 1.5 to 2.0 microns.

Spiral depth: 0.5 to 1.0 microns.

Waves 4 to 6.

Multiplication by transverse division. The body stains bluish-red with Giemsa's stain.

Hay infusion agar: Colonies are like minute drops of moisture, later raised, disc-like, circular, entire, smooth, translucent, grayish white.

Broth: Turbid with grayish-white, wrinkled pellicle.

Aerobic.

Optimum temperature 30°C.

Habitat: In pond water. Not pathogenic.

Genus VI. Leptospira *Noguchi, 1917.*

Parasitic forms. Sharply twisted cylinders with flagelliform tapering ends, one extremity being sharply curved into a "hook."

The type species is *Leptospira icterohaemorrhagiae* (Inado and Ido) Noguchi.

1. **Leptospira icterohaemorrhagiae** (Inado and Ido) Noguchi. (*Spirochaeta icterohaemorrhagiae* Inado and Ido, Jour. of Exp. Med., *23*, 1916, 377; Noguchi, Jour. of Exp. Med., *25*, 1917, 755.)

Cylindrical: 0.25 to 0.3 by 6 to 9 microns, and exceptionally 20 to 25 microns, with pointed ends.

Spiral amplitude: 0.4 to 0.5 micron, regular, rigid.

Spiral depth: 0.3 micron, regular.

Waves, one or more gentle wavy curves throughout entire length. When in free space one or both ends may be semicircularly hooked, while in semisolid media the organism appears serpentine, waved, or bent. The flexibility is most striking.

Axial filament not recognized.

Chambered structure absent.

Membrane not recognized.

Crista absent.

Terminal finely spiral filament not recognized; one or both ends bent into a hook.

Flagella absent.

Highly motile end portion well developed in the last six or eight spirals.

Division transverse.

Staining properties: Membrane not recognizable. Body stains reddish by Giemsa's solution.

Bile salts (10 per cent): Easily dissolved.

Saponin (10 per cent): Completely resistant.
Cultivable in dilute bovine serum.
Aerobic.
Optimum temperature 25°C.
Habitat: The cause of infectious jaundice. Found in the kidney and blood of wild rats.

2. **Leptospira icteroides** Noguchi. (Jour. of Exp. Med., *29*, 1919, 581.)
The organism resembles *Leptospira icterohaemorrhagicae* in its morphologic characters. The spirals are 0.2 to 0.25 by 4 to 9 microns, tapering toward the extremities which are sharply pointed. Multiplies by transverse division.
Can be cultivated in serum water media containing fresh tissue.
Aerobic to microaerophilic.
Optimum temperature 37°C.
Habitat: Regarded by Noguchi as the cause of yellow fever. This organism has not been found in yellow fever patients in Africa. Transmissible to guinea pigs. Disseminated through the bite of *Aedes egypti* (*Stegomyia calopus*).

3. **Leptospira hebdomadis** (Ido et al.) Bergey et al. (*Spirochaeta hebdomadis* Ido, Ito and Wani, Jour. of Exp. Med., *28*, 1918, 435; Bergey et al., Manual, 1st ed., 1923, 430.)
Spiral organisms resembling *Leptospira icterohaemorrhagicae* in their morphologic characters.
Habitat: The cause of "seven day fever" in Japan. Pathogenic for guinea pigs and rabbits. The organism is carried by the field mouse, *Microtus montebelli*.

4. **Leptospira biflexa** (Wolbach and Binger) Bergey et al. (*Spirochaeta biflexa* Wolbach and Binger, Jour. of Medical Research, *30*, 1914, 23; Bergey et al., Manual, 1st ed., 1923, 430.)
Cylindrical: 0.2 to 0.25 by 5 to 7 microns, with tapering ends.
Spiral amplitude: 0.2 to 0.25 microns.
Spiral depth.
Waves, 22 to 30 in number.
Axial filament absent.
Chambered structure not recognized.
Membrane absent.
Crista absent.
Terminal finely spiral filament absent.
Flagella absent.
Highly motile end portion present. Ends bent in form of a crook.
Stains: Best results with Giemsa's stain.
Aerobic.
Optimum temperature 20°C.
Habitat: Isolated from pond water.

INDEX OF THE NAMES OF GENERA AND SPECIES*

(For Index of the Names of Orders, Families, Genera and Groups of Intermediate Rank, See Table of Contents, p. xiii)

***Index prepared by Robert S. Breed, New York Agricultural Experiment Station, Geneva, N. Y.**